CONTRACTOR'S REPORT

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ANAEROBIC FERMENTATION OF ORF WETOX^{R} PEAT PRESSATE FOR THE PRODUCTION OF METHANE

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LIST OF ABBREVIATIONS AND SYMBOLS

a	annum
AP	aerated pond
ALK	alkalinity
BODD	dissolved biochemical oxygen demand
*BODT	total biochemical oxygen demand
BVF	bulk volume fermenter
CODD	dissolved chemical oxygen demand
*CODT	total chemical oxygen demand
d	day
DFF	downflow filter
EFF (or eff)	effluent
g	gram
GC	gas chromatograph
GJ	gigajoule
HRT	hydraulic retention time
INF (or inf)	influent
i.d.	inside diameter
kg	kilogram
kJ	kilojoule
kWh	kilowatt-hour
L	litre
LT	less than
m	metre
mg/L	milligram per litre
MJ	megajoule
mm	millimetre
NRC	National Research Council
o.d.	outside diameter
ORF	Ontario Research Foundation
ppb	parts per billion
ppm	parts per million

SD	standard deviation
SS	suspended solids
SSA	specific surface area
STP	standard temperature and pressure
t	metric tonne
TKN	total kjeldahl nitrogen
TRS	total reduced sulfur
TS	total solids
TVS	total volatile solids
ug/L	micrograms per litre
VA	volatile acids
VSS	volatile suspended solids
≈	approximately

*when expressed as COD or BOD, CODT or BODT is implied.

ABSTRACT

The present study was undertaken to assess anaerobic treatability of WETOX^R peat pressate, using bench-scale models of a high-rate NRC downflow filter and ADI-BVF. The models were operated for approximately eight months. An aerobic model was operated on the BVF effluent to assess its impact on BOD and ammonia removals. Performance was assessed as organic loadings were progressively increased to each anaerobic reactor.

The results of this study revealed the following:

1. WETOX^R peat pressate is amenable to anaerobic treatment, and further work, on a larger scale, should be undertaken to verify preliminary design criteria;

2. The upper practical limit of COD and BOD removals are of the order of 70% and 90%, respectively;

3. The biogas produced would be an excellent fuel for drying purposes and of sufficient quantity to dry the peat-derived fuel from 50 to 62% solids;

4. There was no evidence of biological toxicity;

5. After full maturation of the anaerobic system, it is doubtful that chemicals will be required for pH control, and no nutrients should be required;

6. A relatively high level of solids digestion was observed in the DFF;

7. Ammonia (and possibly hydrogen sulfide) concentrations in the anaerobic effluent will be toxic to fish;

8. Nitrification of the anaerobic effluent is necessary to reduce ammonia concentrations to nontoxic levels;

9. The advantages and disadvantages of discharge of the nitrified (or partially nitrified) effluent to an excavated bog should be studied; and

10. Alternative methods for treatment of the anaerobic effluent should be studied.

RÉSUMÉ

La présente étude a été entreprise pour étudier la possibilité de traiter de la tourbe comprimée WETOX^{MD} par voie anaérobie à l'aide de modèles expérimentaux d'un filtre à écoulement descendant (FED) à haut rendement du CNRC et un fermenteur haute capacité (FHC) de l'ADI. On a fait fonctionner ces modèles pendant approximativement huit mois. On a alimenté un modèle de traitement aérobie avec l'effluent de FHC pour déterminer la capacité du système à abaisser la DBO et à éliminer l'ammoniaque. Pour évaluer l'efficacité du traitement, on a progressivement augmenté la charge organique destinée à chacun des réacteurs anaérobies.

Les résultats de cette étude ont permis de constater ce qui suit:

1. Il est possible de soumettre la tourbe comprimée WETOX^{MD} à un traitement anaérobie; d'autres travaux devraitent étre entrepris à une plus grande échelle pour vérifier les critères de conception préliminaire;

2. Les limites supérieures d'élimination pratique de la DCO et de la DBO sont respectivement de l'ordre de 70 et 90%;

3. Le biogaz obtenu constitue en excellent combustible de séchage qui est produit en quantité suffisante pour sécher le combustible dérivé de la tourbe dont la teneur en solides peut passer de 50 à 62%;

4. Il n'y eut aucun signe de toxicité biologique;

5. Une fois que le système anaérobie aura terminé sa maturation, il ne sera probablement pas nécessaire d'y ajouter des

produits chimiques pour ajuster le pH, ni des éléments nutritifs;

6. On a observé qu'une proportion relativement élevée de solides était digérée dans le FED;

7. Les concentrations d'ammoniaque (et probablement de sulfure d'hydrogène) dans l'effluent anaérobie seront toxiques pour le poisson;

8. Il est nécessaire de nitrifier l'effluent anaérobie pour ramener sa teneur en ammoniaque à une concentration non toxique;

9. Les avantages et les inconvénients du rejet de l'effluent nitrifié (en totalité ou en partie) dans excavation pratiquée dans une tourbière devraient être étudiés;

10. D'autres méthodes de traitement applicables à l'effluent anaérobie devraient être examinées.

1.0 CONCLUSIONS AND RECOMMENDATIONS

1.1 Conclusions

The major conclusions resulting from this study are listed below in point form.

1. The results of this study indicate that WETOX^{R} peat pressate can be effectively treated in both the high-rate DFF and low-rate BVF.

2. The results of this study, and past experience, suggest COD loadings of 8.0 kg/m^3.d and 1.7 kg/m^3.d for the DFF and BVF, respectively, for a COD removal of approximately 60 percent, are reasonable (and felt to be conservative) for preliminary design purposes.

3. The practical limits of COD and BOD removals are in the range of 60-70 percent and 80-90 percent, respectively.

4. Approximately 40 percent of the chemical energy in the peat pressate effluent can be recovered, as biogas, through anaerobic treatment. This biogas contains approximately 6.0 to 6.5 percent of the energy content of the peat-derived fuel product.

5. The biogas production rate from the reactors was typical, with the specific methane generation rate averaging 0.31 and 0.35 m^3 CH_4/kg COD destroyed for the DFF and BVF, respectively.

6. The concentration of methane in the biogas for both reactors varied from approximately 50 to 85 percent, primarily in response to changing reactor pH. In a full-scale system, the biogas composition would show much less variation, and the methane content should be in the 65 to 75 percent range. Hydrogen sulfide concentrations were relatively low in both reactors and should cause no serious handling or environmental problems in full scale.

7. The raw biogas should be an excellent fuel for thermal drying of the peat-derived fuel; there are sufficient quantities available to raise the solids content of the mechanically dewatered peat from 50 to 62 percent. If higher solids are necessary, the peat-derived fuel can also be utilized as a fuel source for drying.

8. There was no evidence of biological toxicity or inhibition in either anaerobic reactor. Toxicity from furfural, hydrogen sulfide or ammonia are unlikely unless the characteristics of the pressate change drastically from those observed in this study.

9. The upset condition which occurred in the DFF is believed to be the result of low reactor pH caused by a deliberate lowering of the reactor alkalinity. It is felt that there will be no need for pH control chemicals in either type of reactor, at moderate loadings, once the reactors have fully matured.

10. The results of this study indicate that there are adequate levels of macro and micronutrients in the WETOX^{R} pressate for anaerobic fermentation.

11. Solids mass balance data indicate that approximately 75 percent of the suspended solids retained in the reactors were digested anaerobically during this short study. Further solids degradation will occur with time.

12. Solids wasting will be necessary in both reactors. Solids wasting from the DFF is accomplished automatically and is inherent in its design. Solids wasting in the BVF will not be required until after several years of operation, when the effluent quality begins to suffer because of excess sludge in the reactor. Because of its long SRT, the BVF will provide a very high degree of volatile solids digestion and can be used as a digester for any waste aerobic sludge.

13. Ammonia, and possibly hydrogen sulfide, concentrations in the anaerobic effluent will be toxic to trout. Conventional aerobic treatment will eliminate hydrogen sulfide and further remove BOD; however, to ensure adequate reduction of ammonia, to produce a nontoxic effluent, will require a nitrification system. Such a system is more costly, complex and difficult to operate.

14. The nitrate concentration in the aerobic effluent should not be toxic to fish; however, there is a potential for toxicity from nitrite if significant residuals remain upon discharge.

15. The high nitrate concentrations can be a cause for concern if the effluent is not sufficiently diluted before entering streams or aquifers used for drinking purposes.

16. A possibly better alternative to discharging the nitrified effluent directly to a receiving stream would be to discharge to an excavated bog area. Perhaps disposal in this manner would preclude extensive aerobic polishing. Discharging to the bog should provide additional dilution and a significant degree of denitrification.

17. An alternative to nitrification is ammonia stripping. However, it is unlikely that stripping can be done, cost-effectively, to the extent necessary to preclude a nitrification step altogether.

18. The estimated capital cost for a full-scale DFF and modified BVF, complete with 10-day aerated pond, is approximately $2.2 million and $1.4 million, respectively. These costs are for systems treating effluent from a WETOX^{R} plant processing 50 tonnes per hour of peat slurry at 10 percent solids. Larger anaerobic reactors can be designed and built at lower unit cost. This is especially significant in the case of the BVF because of its earthen construction. The estimated annual operating and maintenance costs for the DFF and modified BVF are $135 000 and $110 000, respectively.

1.2 Recommendations

The following recommendations are made in light of the findings of this study.

1. A pilot or demonstration-scale study should be undertaken to verify the preliminary anaerobic design criteria developed here.

2. Further research work should be conducted on alternative methods for treatment of anaerobic effluent. It should include ammonia removal and nitrification studies and, possibly, toxicity studies.

3. There appears to be definite advantages for the discharge of the nitrified effluent (or partially nitrified) into an excavated bog area. Further study is necessary to determine the full environmental impact such a discharge will have and to determine if it merits serious consideration in full scale.

2.0 INTRODUCTION AND BACKGROUND INFORMATION

The rapidly increasing interest in alternative fuels has focused interest on peat as one of a number of nonconventional energy sources in Canada. In comparison with other peat-producing countries, Canada has large resources of peat. According to a recent estimate, Canada's potential/inferred total peatland area is over 50 million hectares.

The use of peat as an energy source, in Canada, has been hampered by the availability of cheaper energy alternatives and by climatic conditions which have slowed development of harvesting techniques. In order to overcome the climatic limitations and also those of scale and environmental concerns, wet mining methods have been developed and are in the early stages of commercialization. Wet mining techniques will allow near-continuous operation and lower the costs of mining peat.

One of the major technical and economic hurdles associated with the utilization of peat as an energy source is the reduction of its water content. In its natural state, peat can contain over 90 percent water; in the case of wet-mined peat, the water content can be as high as 99 percent.

A moisture content of 50 percent or less is required for efficient, direct combustion; a lower moisture content is both desirable and beneficial. There are a number of technologies for the beneficiation of peat to produce a material with low moisture content for direct combustion or for processing into specialty products.

Raw peat has such an affinity for water that it is impractical to reduce its water content below 70 percent by the application of pressure alone. However, through heat treatment, the peat can be dewatered to 50 percent solids with the same dewatering equipment.

The heat treatment of raw peat involves heating the peat slurry under pressure which, in a sense, is just a cooking process. The purpose of this treatment is to free the water bound in the microstructure of the peat and, thus, reduce the cost for dewatering. The treatment also produces physical and/or chemical changes which result in better retention of colloidal and other suspended solids in the subsequent dewatering step; it also increases the unit heating value and enhances the storage, transportation and handling characteristics of the peat-derived fuel.

Heat treatment falls into two major categories, viz., partial wet oxidation and wet carbonization. The difference between these two processes is in their primary heat sources. The partial wet oxidation process generates most of its heat internally by the wet combustion of up to 10 percent of the raw peat. In wet carbonization, heating is obtained by an external source, such as steam.

The major disadvantage of heat treatment of peat is the resultant chemical changes and dissolution of substances which results in a strong waste effluent. Depending on the severity of treatment, up to 20 percent of the original peat can be dissolved. The waste effluent is produced when the heat-treated peat is subsequently dewatered. Another source of pollution, albeit a relatively minor one, is the condensate from the heat treatment step.

The solubilized substances in the effluent and solid peat lost in the dewatering step represents a significant product and economic loss. Moreover, it contains substances known to be deleterious to the environment, and therefore, treatment of the effluent is considered necessary. The cost of treatment can represent a further, significant economic penalty against heat treatment processes.

Conventional forms of aerobic wastewater treatment can be very costly, especially with this type of effluent which contains high concentrations of BOD and ammonia. Experience has shown that, in many wastewater applications, anaerobic treatment is a very cost-effective treatment option. Its cost-effectiveness is primarily the result of the process not requiring aeration to maintain proper levels of biological activity and the generation of biogas. This biogas is a combustible mixture of methane and carbon dioxide and is valuable as a fuel gas.

Anaerobic pretreatment followed by aerobic polishing has, in fact, been suggested for treatment of peat heat treatment effluent. Preliminary work on ORF WETOX^{R} peat pressate[1] has demonstrated its treatability. It has been proposed that the biogas produced in the anaerobic fermenter be used in thermal drying of the peat-derived fuel.[1] Utilization of this biogas improves the overall energy balance and economics of the WETOX^{R} system.

At present, there is very little data regarding the anaerobic or aerobic treatability of peat heat treatment effluent. This is one area where further R & D work has been recommended.[2] The present study was undertaken to determine the suitability of anaerobic fermentation for treatment of peat WETOX^{R} pressate and to better define the economics of full-scale anaerobic treatment systems.

3.0 THEORY

Anaerobic fermentation is the biological conversion of organic materials to methane, carbon dioxide and other inorganic compounds in the absence of oxygen. Over a century ago, anaerobic decomposition was first reported to be a useful means of reducing and stabilizing solid material from domestic wastes. In the years that have followed, the knowledge and interest in this technology has grown. This is especially true at the present time because of its tremendous potential for methane generation and savings.

The use of anaerobic treatment has recently found a much broader application, especially in industry and agriculture. This has come about through the development of several new types of anaerobic systems and, more importantly, a better understanding of process controls and variables.

Presently, it is believed that anaerobic fermentation is carried out by four essential and interdependent groups of bacteria. This interdependent digestion process is shown in Figure 3.1.[3] This fermentation process is well suited for digestion of both soluble and insoluble wastes.

Stage One in the conversion of complex organic wastes (which includes carbohydrates, proteins and lipids) to methane involves hydrolysis and fermentation to fatty acids, alcohols, carbon dioxide, ammonia and hydrogen. In Stage Two, acetogenic bacteria convert the products of the acid-forming bacteria into hydrogen, carbon dioxide and acetic acid.

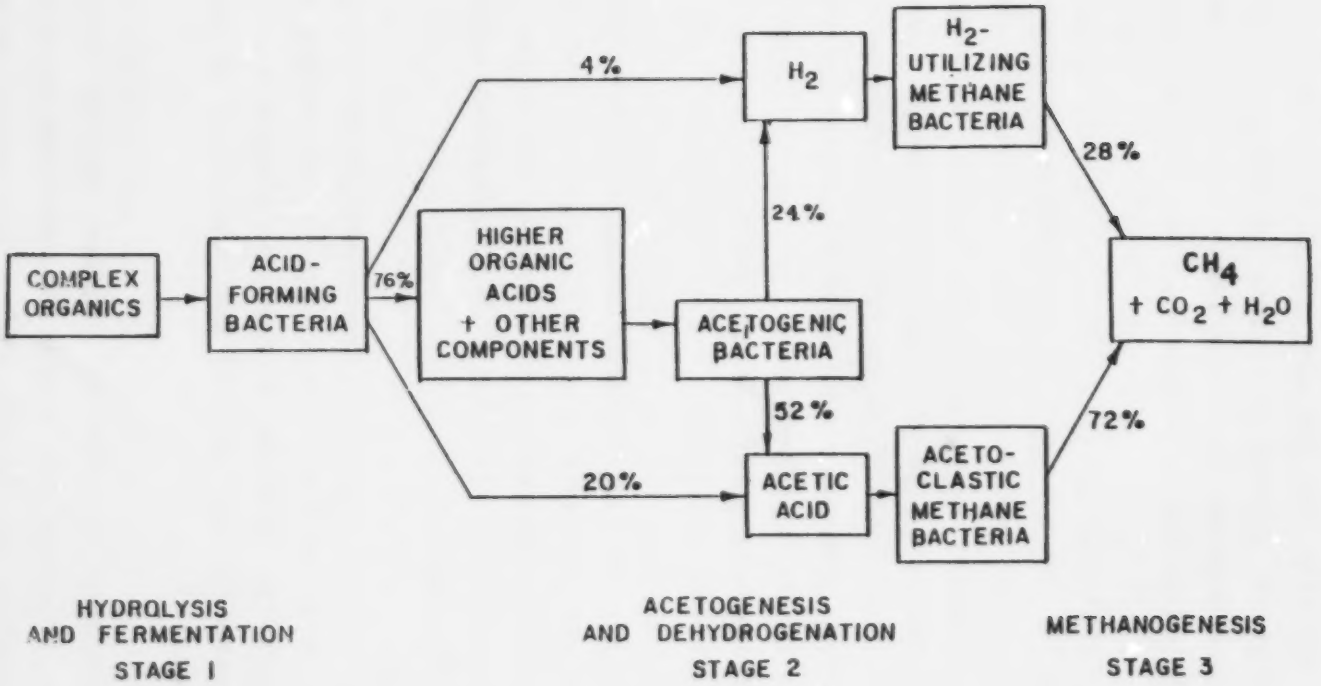


FIGURE 3.1

The three stages of methane fermentation and the percentage flow of the energy content of complex organic materials through each stage into methane as represented by the chemical oxygen demand (adapted from (3))

Stage Three, the final conversion to methane, takes place via two groups of bacteria: acetoclastic methane bacteria and hydrogen utilizing methane bacteria. The former produces methane (and carbon dioxide) from the decarboxylation of acetic acid, while the latter utilizes hydrogen and carbon dioxide, two of the products of the acetogenesis phase, to form methane and water.[4]

Figure 3.1 also indicates the portion of waste COD which is converted by the various routes. It shows that over 70 percent of the methane results from the fermentation of acetic acid.

The dissolved substances in WETOX^{R} peat pressate are primarily simple organic acids which, through the acetogenic and aceto-clastic methane bacteria, are converted to methane (CH_4), carbon dioxide (CO_2) and water (H_2O).

4.0 OBJECTIVES

The objectives of this study are presented below in point form:

1. to verify anaerobic treatability of ORF WETOX^{R} peat pressate using both the NRC-DFF and the modified ADI-BVF;

2. to assess the performance of both the DFF and modified BVF in terms of BOD/COD removal, as a function of organic loading and biogas production;

3. from the results obtained in number 2 above, develop preliminary design criteria for full-scale reactors and specific methane generation rates;

4. to develop preliminary capital and net annual costs for full-scale DFF and BVF systems; and

5. to recommend where further R & D is required.

The above objectives were met through a bench-scale laboratory study which lasted approximately 35 and 31 weeks for the DFF and BVF models, respectively. During the laboratory study, the organic loading on each reactor was progressively increased and its performance assessed in an effort to identify an optimum loading for each reactor.

The design criteria produced from the above study were then used to develop the capital and operating costs associated with each reactor type (reference Section 11) and to project the quantities of methane (energy) recovered in treatment. These costs were developed for a hypothetical WETOX^{R} system capable of processing 50 tonnes per hour of raw peat slurry at 10 percent solids.

While not a requirement of this study, a bench-scale, 10-day, complete-mix, aerated pond was modelled to treat BVF effluent. This additional work was undertaken as this study presented an excellent and very inexpensive opportunity to investigate aerobic polishing of the anaerobic effluent.

5.0 CHARACTERISTICS OF WETOX^R PEAT PRESSATE AND SUPPLEMENTS

5.1 General

The peat pressate waste used in this study was produced by ORF using the partial ORF WETOX^R process. Details of the conditions for production of the waste are given in Appendix A. The raw peat used as feed had the characteristics shown in Table 5.1 below.

TABLE 5.1 - RAW PEAT AND PRESSED CAKE CHARACTERISTICS[5]

	Raw Peat	Pressed Cake
Humification (von Post)	H6-H9	-
Moisture as received (%)	93.9	69.1
Ash (%)	14.7	15.7
Volatiles (%)	59.9	55.2
Fixed carbon (%)	25.4	29.2
Nitrogen (%)	1.65	1.60
Carbon (%)	52.0	53.8
Hydrogen (%)	4.7	4.3
Sulphur (%)	0.24	0.19
Oxygen by difference (%)	26.8	24.5
Gross calorific value (MJ/kg)	22.9	23.1

The peat was obtained from a shallow bog in Quebec, about 100 km east of Montreal.

The COD and TS of the feed peat was 98 920 and 70 674 mg/L, respectively.

5.2 WETOX^{R} Peat Pressate

The WETOX^{R} peat pressate was produced by ORF in three separate runs and shipped to ADI's laboratory in Fredericton in 45-gallon plastic drums. The contents of each drum were then thoroughly mixed and transferred into 5-gallon containers. The pressate was then frozen in these containers until it was needed as feed for the anaerobic reactors.

Following receipt of each run, a sample was collected specifically for a "complete" analysis which included metals. Table 5.2 lists the chemical characteristics of the peat pressate.

5.3 Supplements

To ensure that the biological activity would not be limited by macronutrients, a BOD/N/P ratio of 200/5/1 was maintained by the addition of NH_4Cl and KH_2PO_4. Following several analyses, it was determined that the pressate contained an adequate supply of nitrogen, and the addition of NH_4Cl was subsequently dropped. The pressate was also supplemented for a short period of time with small dosages of yeast extract, to ensure an adequate supply of micronutrients. The amount of yeast extract added can be found in Tables 7.1 and 7.3 which list and date the various operating changes made during the study. The typical characteristics of the yeast extract are given in Table 5.3.

TABLE 5.2 - ANALYSIS OF RAW PEAT PRESSATE WASTE

Parameter	Concentration		
	Sample #1	Sample #2	Sample #3
Date Received	84/03/15	84/04/04	84/06/12
BODT	2 830 U	3 960 U*	4 360 S
BODD	2 700 U	3 750 U	4 250 S
CODT	9 500	11 100	11 800
CODD	8 200	10 800	9 000
TKN	390	450	438
NH_3-N	210	240	177
Total Phosphorus	15.8	18.5	13.9
Total Sulfur	162	272	292
SO_4	124	220	154
H_2S (total)	2.2	3.8	0
H_2S (soluble)	2.2	3.8	0
TS	6 496	9 380	9 405
TVS	5 304	7 912	7 836
SS	518	366	268
VSS	408	304	268
VA	2 699	2 977	1 959
ALK	0	0	0
pH	3.4	3.3	3.4
Ca	298	330	295
Cd	<0.01	<0.01	
Co	<0.02	<0.02	
Cr	0.05	0.14	
Cu	0.07	0.01	
Fe	57.2	77.6	63.7
Hg (ug/L)	<0.2	<0.2	
K	5.1	4.22	
Mg	19.5	17.8	17.8
Na	16.6	9.25	8.2
Ni	<0.1	0.11	
Pb	<0.05	<0.02	
Se	<0.1	<0.1	
Zn	0.27	0.56	
Furfural		7.54	

Notes:

1. All results in mg/L unless otherwise indicated.

2. *; Ontario Research Foundation reported seeded and unseeded total BODTs of 5170 and 5055, respectively.

3. U = unseeded; S = seeded.

TABLE 5.3 - CHARACTERISTICS OF YEAST EXTRACT

Parameter	Result
Ash	10.1
Total N	9.18
Arginine	0.78
Aspartic acid	5.1
Glutamic acid	6.5
Glycine	2.4
Histidine	0.94
Isoleucine	2.9
Leucine	3.6
Lysine	4.0
Methionine	0.79
Phenylalanine	2.2
Threonine	3.4
Tryptophane	0.88
Tyrosine	0.60
Valine	3.40
Phosphorus	0.29
Iron	0.028
SiO_2	0.052
Potassium	0.042
Sodium	0.32
Magnesium	0.030
Calcium	0.040
Chloride	0.190
Manganese (ppm)	7.8
Lead (ppm)	16.00
Arsenic (ppm)	0.11
Copper (ppm)	19.00
Zinc (ppm)	88.00
Pyridoxine (ppb)	20.0
Biotin (ppb)	1.4
Thiamine (ppb)	3.2
Nicotinic acid (ppb)	279.00
Riboflavin (ppb)	19.00

Notes: 1. All results in percent by weight unless otherwise indicated.

2. From information supplied by Difco Laboratories, 1953 Difco Manual, Ninth Edition, Difco Laboratories, Detroit, Mi.

6.0 BENCH-SCALE MODELS

Two bench-scale models, an anaerobic downflow filter (DFF) and a modified bulk volume fermenter (BVF), were used to treat ORF WETOX^{R} peat pressate. The temperature of both models was maintained at 35^{o}C. The effluent from the BVF was used as feed for a ten-day aerated pond. Schematics of the DFF and BVF systems are presented in Figures 6.1 and 6.2. In the sections that follow, a brief description of each model is given.

6.1 Downflow Filter

A section of the high-rate downflow filter is shown in Figure 6.3. This model had a total volume of approximately 2.5 litres and a liquid volume of 2.4 litres. The DFF was developed at the National Research Council (NRC)[6,7] as a consequence of the anaerobic filter developed by Young and McCarty.[8] It was so named because of its downward (vertical) flow pattern and the support media which has characteristic, continuous vertical channels. The DFF was developed in an effort to minimize plugging problems, due to bacterial solids and influent suspended solids accumulations.

A comparison of the DFF with other reactors has been made by various authors, including Van den Berg and Kennedy[9] and Hall.[10] In the DFF, biomass slough and other settleable, undigested solids are removed in the effluent, thereby reducing the risk of media plugging. Mixing within the reactor and sloughing of biomass is promoted by the action of rising gas bubbles in the media channels.

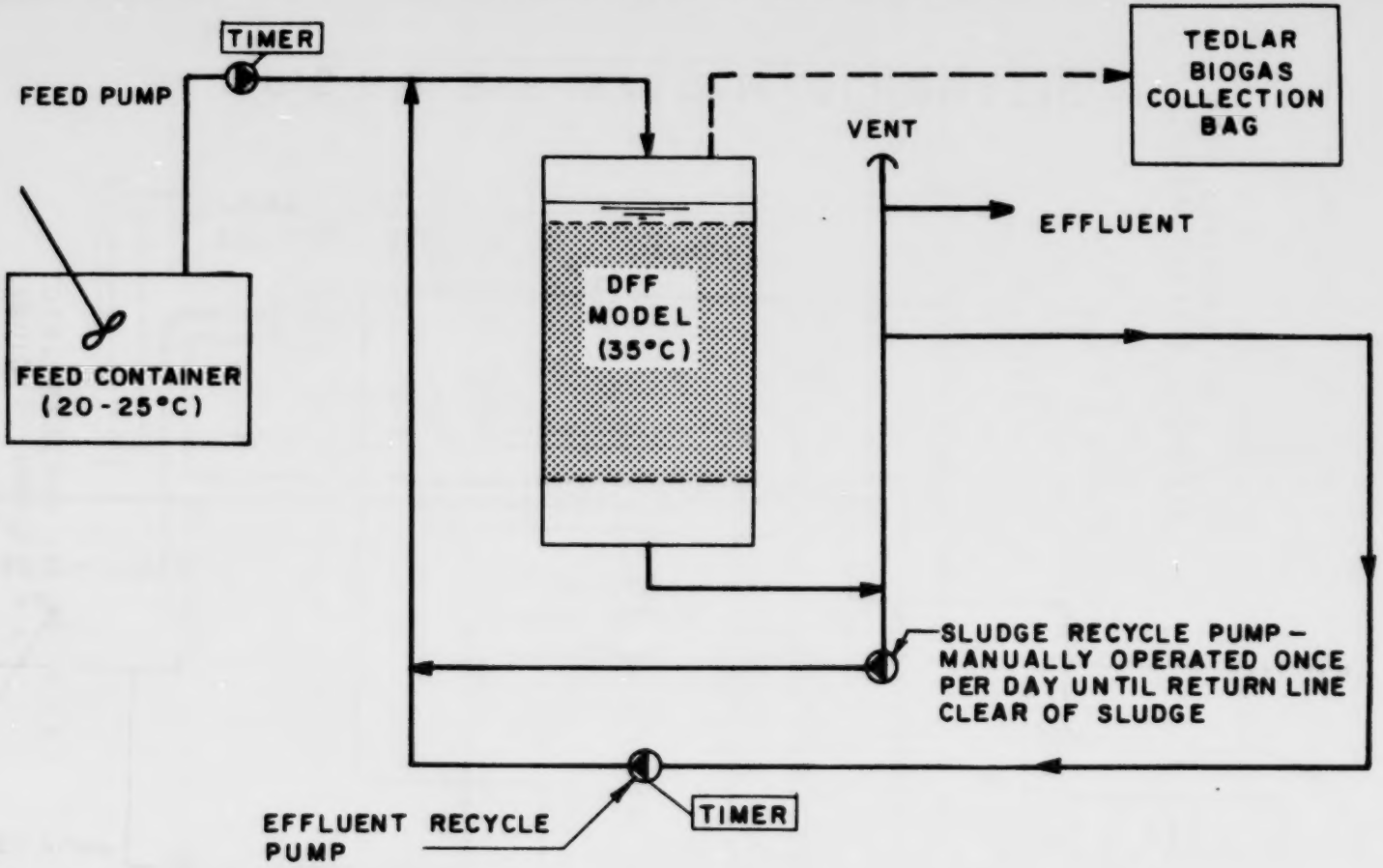


FIG 6.1: DFF SYSTEM SCHEMATIC

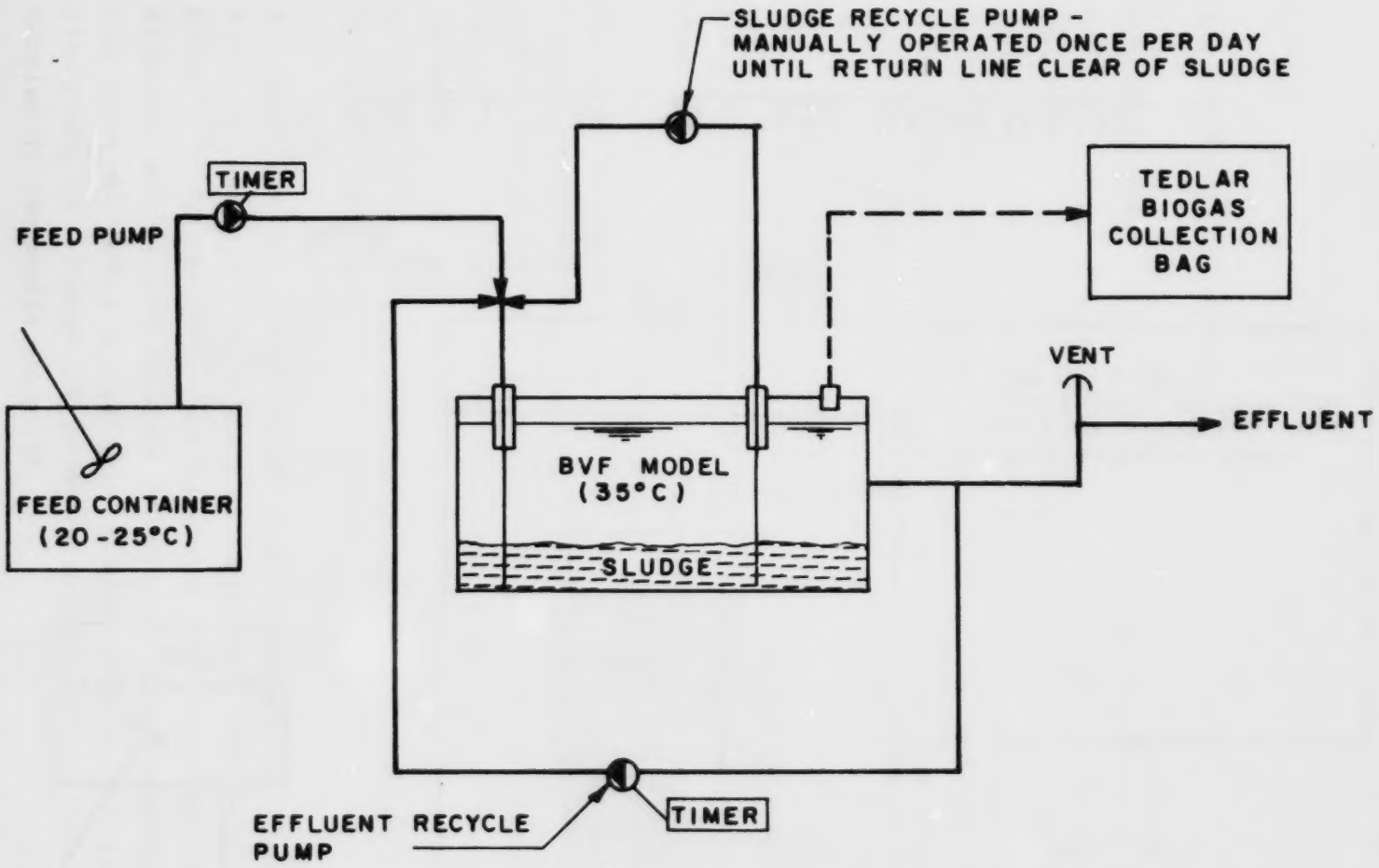
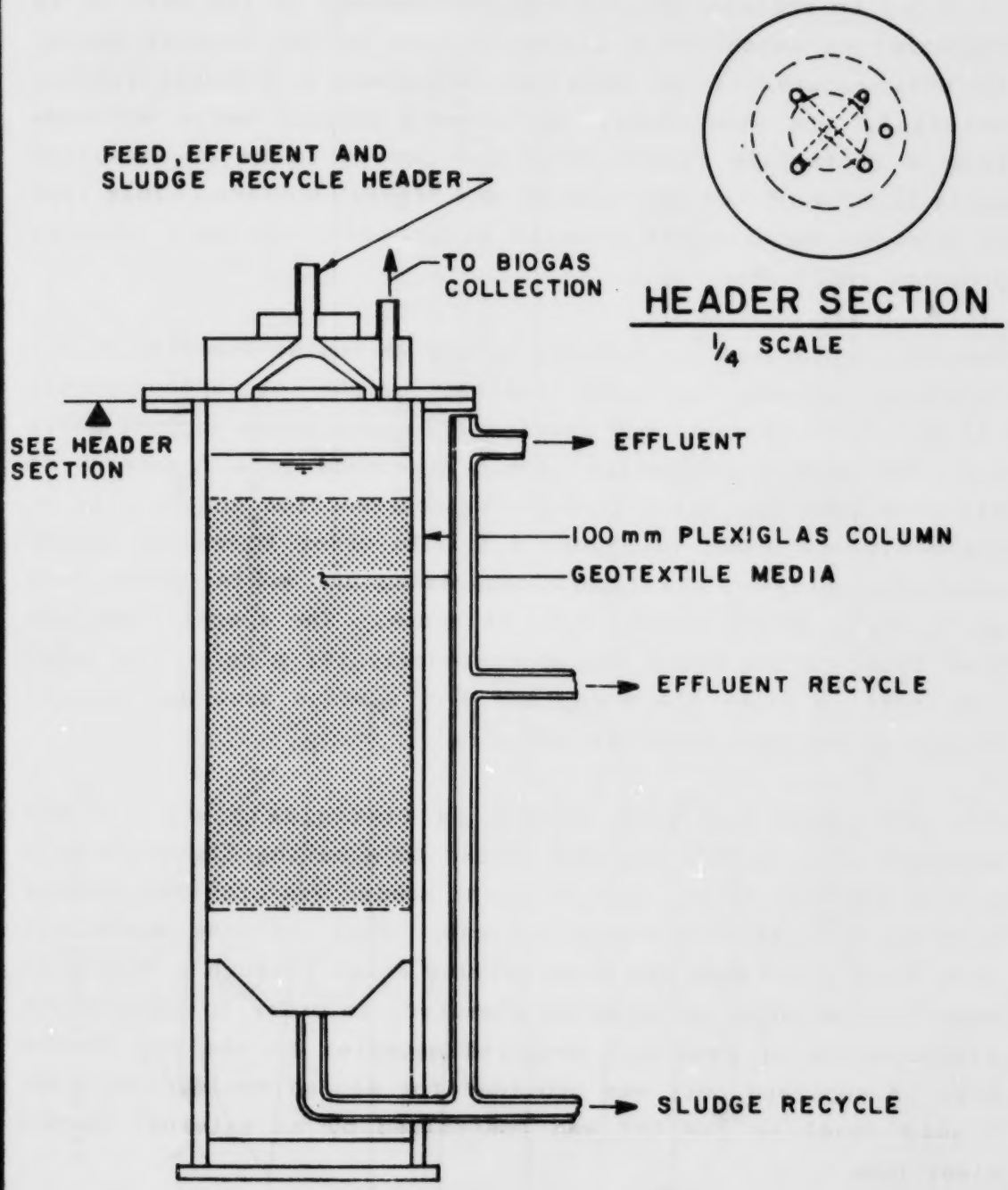


FIG 6.2: BVF SYSTEM SCHEMATIC



HEADER SECTION
1/4 SCALE

TOTAL REACTOR VOLUME = 2.5 L
LIQUID VOLUME = 2.4 L
(INCLUDING MEDIA)

FIG 6.3: DFF SECTION
1/3 SCALE

In order to achieve satisfactory performance in the DFF, it is essential to establish a stable biomass on the support media. In this regard, it is important to select a suitable packing material. In this study, the biomass support media was made from a geotextile fabric which has proven to be an excellent media because of its very porous and "fuzzy" surface. This type of surface facilitates biomass attachment and, as a result, promotes rapid start-up.

The DFF reactor was constructed of 100 mm inside diameter (i.d.) Plexiglas column (with an overall height of approximately 350 mm). As was mentioned previously, the biomass support media was made from a geotextile fabric stretched on a framework of aluminum rods and nylon rings. A cross-section and details of the media are shown in Figure 6.4. In order to ensure proper separation between the layers comprising the media, glass rods were placed between each layer of cloth. The specific surface area (SSA) of the media was approximately 141 m^2/m^3. The total SSA (total = cloth SSA + reactor wall surface area not covered by cloth) was approximately 153 m^2/m^3.

The DFF cover was made from 6 mm Plexiglas plate; it was equipped with an "O" ring and bolted to a mating flange to produce a gastight sytem. One influent header was provided for the feed and effluent and sludge recycle. This influent header was then split four ways via 9 mm drilled holes through a Plexiglas block, 25 mm thick by 95 mm in diameter, in order to improve the distribution of feed and recycled material to the top of the DFF. A separate port was provided for biogas collection. The liquid level in the DFF was controlled by an external vented riser tube.

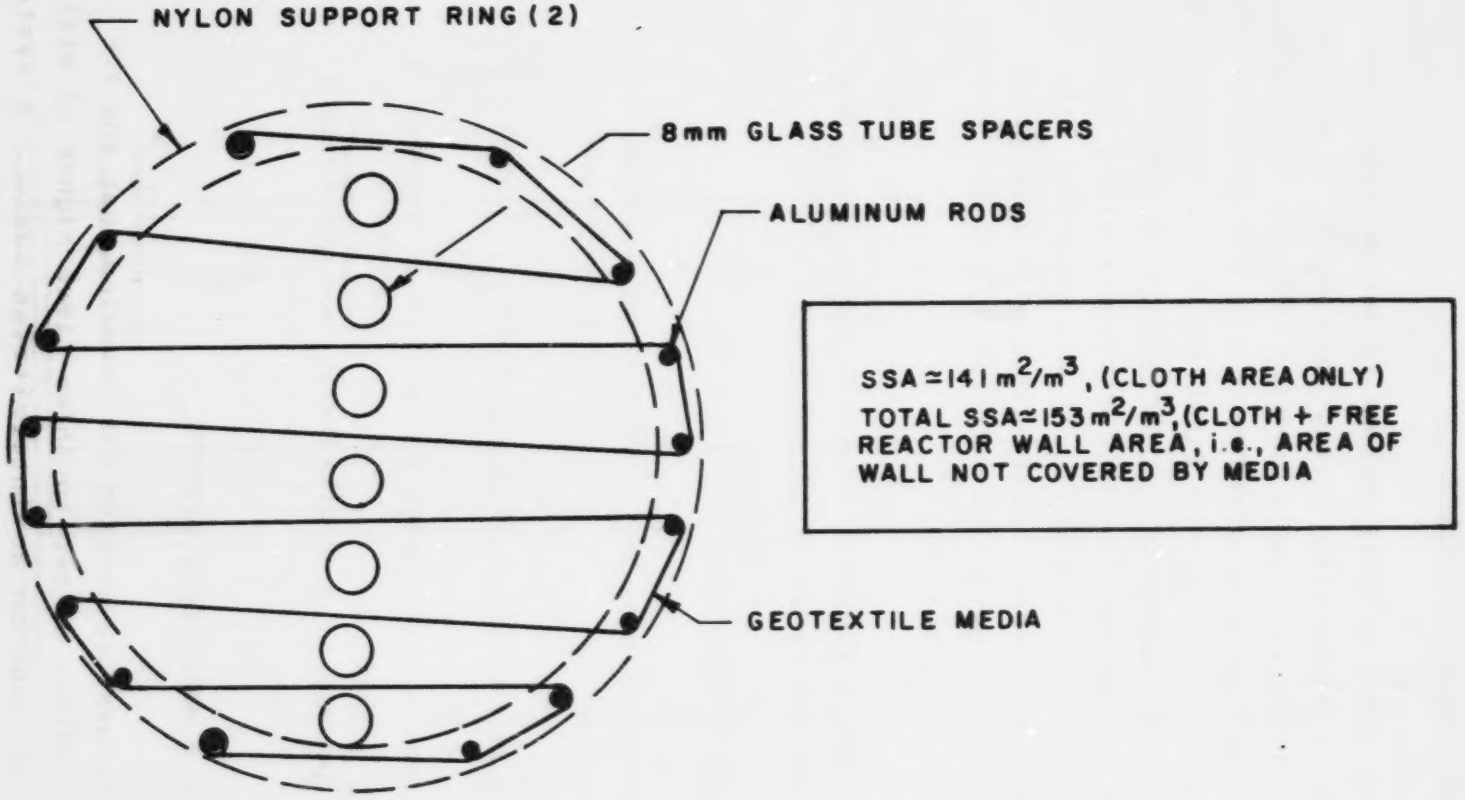

NYLON SUPPORT RING (2)
8mm GLASS TUBE SPACERS
ALUMINUM RODS
SSA ≃ 141 m²/m³, (CLOTH AREA ONLY)
TOTAL SSA ≃ 153 m²/m³, (CLOTH + FREE REACTOR WALL AREA, i.e., AREA OF WALL NOT COVERED BY MEDIA
GEOTEXTILE MEDIA

FIG 6.4: DFF MEDIA CROSS-SECTION

FULL SCALE

6.2 Modified Bulk Volume Fermenter

A second model, a modified bulk volume fermenter (BVF) (reference Figure 6.5), was operated during this study to provide a means of comparison between the high-rate DFF and the low-rate BVF, in the treatment of peat pressate. The BVF is an adaptation of the anaerobic lagoon, the first anaerobic system to be applied to industrial wastewaters. As mentioned above, it is considered to be a "low rate" system, reflecting its typically low loading rate (1 kg COD/m^3.d). It has recently been used successfully in two full-scale applications with food processing waste.[11,12] The BVF is quite different from the anaerobic lagoon for the following reasons:[13]

(1) it utilizes a floating membrane cover for biogas collection and temperature and odour control;

(2) it incorporates biogas utilization;

(3) it employs effluent and sludge recycle to enhance performance;

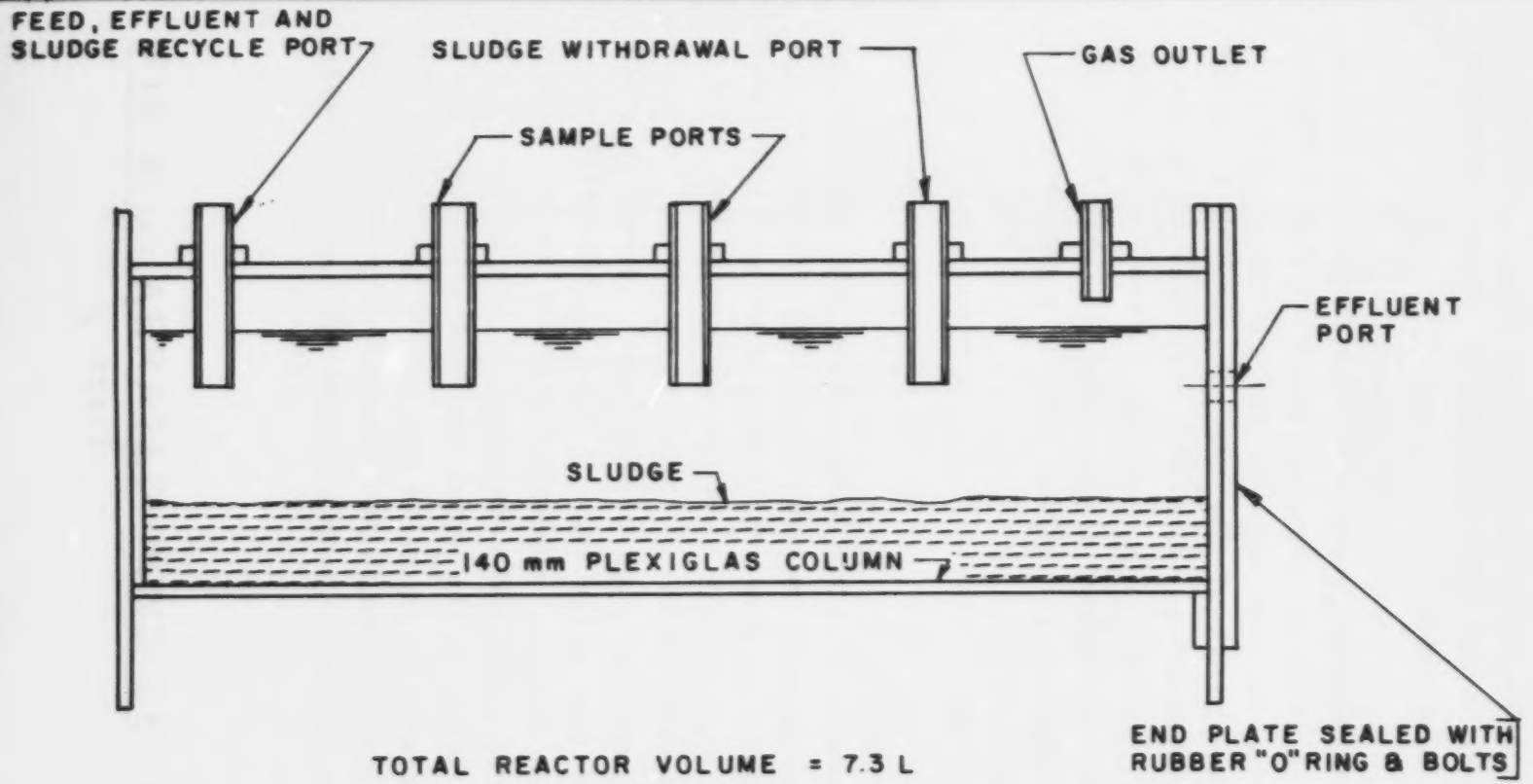
(4) it provides on-stream sludge removal;

(5) it utilizes special inlet and outlet arrangements;

(6) it has provision for alkalinity and pH control; and

(7) includes a monitoring system.

Recent in-house laboratory testing has revealed that the BVF can be operated at loadings of two to three times higher if mixing of the reactor is done on an intermittent basis. A system



TOTAL REACTOR VOLUME = 7.3 L
LIQUID VOLUME = 6.7 L
(INCLUDING SLUDGE)

FIG 6.5 : BVF SECTION

1/3 SCALE

operating in this mode is termed a "Modified BVF." The model used here was operated in the modified mode by gently agitating the reactor contents once daily.

The BVF reactor used in this study was constructed of 140 mm i.d. Plexiglas tubing (with an overall length of approximately 490 mm). Liquid level in the BVF was maintained at approximately 25 mm from the crown of the reactor, giving a liquid volume of approximately 6.7 L. One end cover was permanently fixed to the model, while the other was removable and made liquid and gastight with suitable "O" rings and bolts. Provision was made for effluent and sludge recycle ports as well as a port for biogas collection.

6.3 Aerated Pond

A ten-day, complete-mix, aerated pond, using BVF effluent as feed, was operated to monitor the additional BOD removal and the degree of nitrification obtained following anaerobic treatment (reference Figure 6.6). It was constructed from a 100 mm i.d. Plexiglas column section, with an overall height of approximately 245 mm. A cover made of plastic and clamped in place prevented the liquid from splashing. A feed line consisting of 13 mm i.d. Plexiglas tubing, approximately 300 mm in length, penetrated the plastic cover and terminated at the bottom of the model. The liquid level in the model was controlled by a 13 mm o.d. effluent port placed 35 mm below the top of the model, thus giving a liquid volume of approximately 1.7 L. Aeration was accomplished using a Hagen air pump equipped with an air dispersion stone.

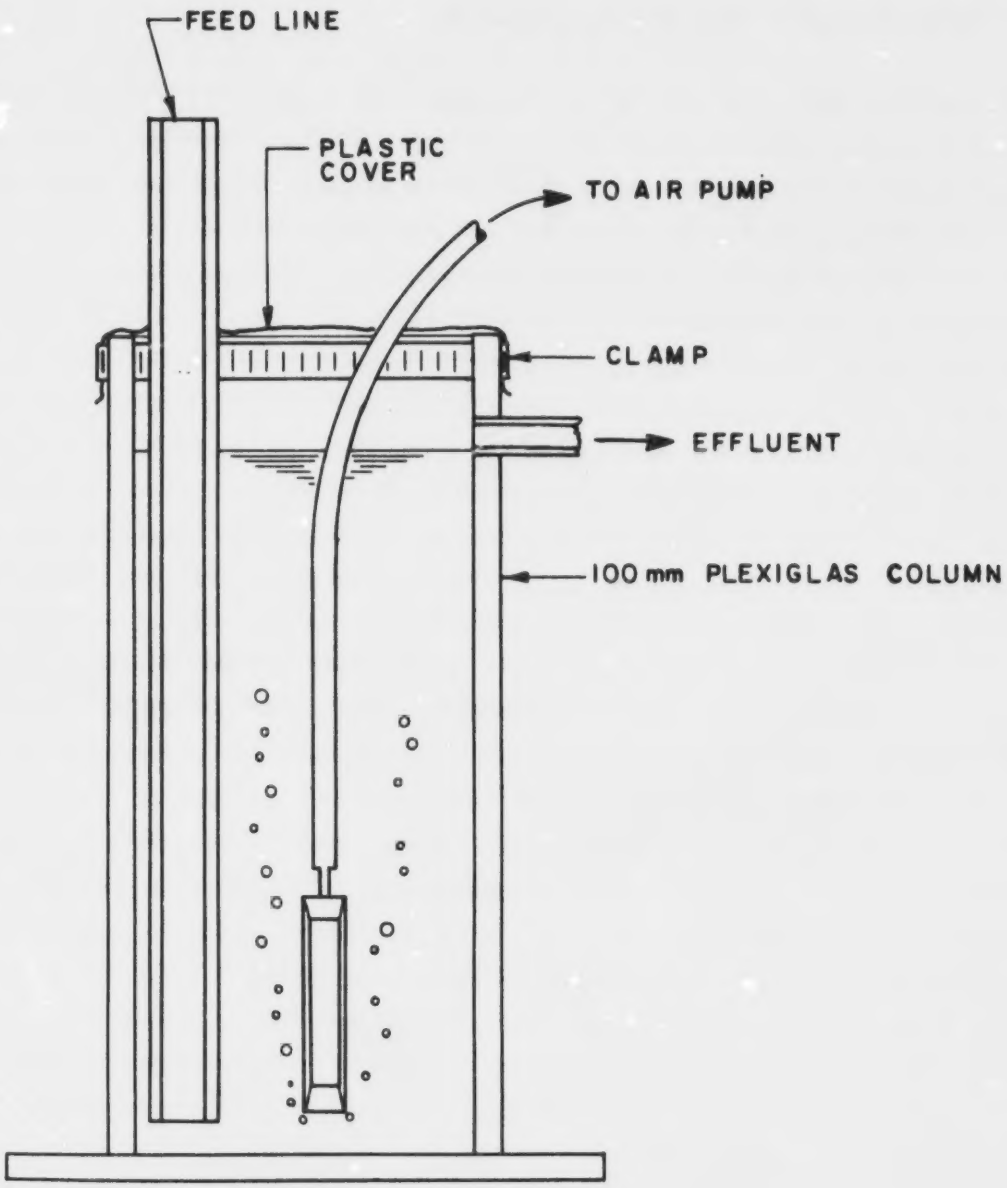


FIG 6.6 : AERATED POND SECTION

1/2 SCALE

6.4 Feed, Recycle and Biogas Systems

In both the DFF and the BVF, the feed rate was controlled by a variable-speed peristaltic pump and a timer. Feeds for both models were mixed while the models were being fed. The feed was prepared weekly and kept at room temperature (20-25^{o}C) to minimize its degradation. Effluent recycle was accomplished using a peristaltic pump and timer; the BVF effluent recycle:feed ratio was 1:1, while the DFF ratio was varied from 1:1 to 5:1. Sludge recycle was also accomplished in each model using a peristaltic pump; in this case, the sludge recycle pump was operated manually once per day until the return line was clear of sludge.

Biogas from each model was collected, measured and analyzed to determine the specific methane generation rate. The biogas was collected in Tedlar (polyvinyl fluoride) gas sampling bags (8 L capacity each) prior to measurement. Gas measurement was by displacement of an acidified salt solution, as specified in Standard Methods.[14]

7.0 MODEL OPERATIONS

7.1 Seeding and Start-up

Table 7.1 outlines the operation of the DFF model. This DFF had been previously used for treatment of potato processing wastewater. It contained a viable biomass, but of unknown characteristics. To this reactor was added 100 mL of sludge from a working bench-scale BVF that was treating a pulp and paper wastewater; this sludge had a TS and TVS of 1.9 and 0.65 percent, respectively.

Between days 1 and 107, the DFF was acclimated using a 10 percent by volume mixture of black liquor and water. The dilute black liquor was believed to be somewhat similar in waste characteristics to the WETOX^{R} peat pressate. The black liquor was spent pulping liquor from a Canadian semichemical mill (carbonate cook). Table 7.2 documents the chemical characteristics of the full-strength black liquor. During the acclimation period, the DFF was batch-fed once daily. A BOD/N/P ratio of 200/5/1 was maintained by the addition of N (as NH_4Cl) and P (as KH_2PO_4).

On day 107, the ORF WETOX^{R} peat pressate waste became available and was fed to the DFF in a 25 percent by volume mixture of pressate and water. From day 107 on, while both models were operating, the feeds to the DFF and BVF were identical in all respects and were fed using a peristaltic pump and timer system. The BOD/N/P ratio was maintained at 200/5/1, while $NaHCO_3$ was added for pH and alkalinity control.

Between days 107 and 119, the feed strength was gradually increased from 25 percent to 100 percent by volume; thereafter, 100 percent feed strength was maintained.

Initially, the DFF and its feed container were kept at room temperature (approximately 25°C). On day 87, while still in the acclimation period, the reactor was transferred to the 35°C chamber; the feed container was kept at 25°C to minimize degradation of the waste between feed preparation periods (i.e., one-week intervals).

Table 7.3 outlines the operation of the BVF model. The BVF seed sludge was acclimated in a "bucket" reactor. The seed sludge volume totaled approximately 3 litres. It was made from a mixture of sludge from two working bench-scale models, one treating a food processing waste and the other, a pulp and paper waste. This sludge mixture had TS and TVS concentrations of 2.0 percent and 0.84 percent, respectively. On day 43, an additional 1 litre of seed sludge (TS = 1.9 percent, TVS = 0.98 percent) was added to the reactor. The BVF start-up and acclimation period began on day 41 (reference Table 7.3). The BVF feed during acclimation was the same mixture used for the DFF (i.e., a 10 percent mixture of black liquor and water).

On day 57, the contents of the "bucket" reactor were transferred to the BVF model, which is described in Section 6.2. On day 87, the BVF was transferred from the 25°C to the 35°C chamber. From day 87 to 119, the acclimation procedure continued as in the case of the DFF.

7.2 DFF Operations

The treatability of the peat pressate using the DFF technology was assessed. The loading to the DFF was gradually increased to approximately 2.5 kg BOD/m^3.d (6.0 kg COD/m^3.d) by increasing the feed rate. During the study, the performance of the DFF was monitored continuously. The effluent (to feed) recycle ratio was set at 1:1 from days 57 to 148. Prior to that, no effluent recycle was done. On day 148, the recycle ratio was changed to 5:1 to ensure good distribution of substrate within the reactor; it remained at that value until day 153 when it was changed to 3:1. The recycle ratio was finally changed to 2:1 on day 160 and remained at that value until the end of the study. Supplements were added to the feed to provide pH and alkalinity control and an adequate supply of micro and macronutrients. Various dosages of chemicals were used; these are documented in Table 7.1.

Due to rising levels of volatile acids and falling pH in the reactor effluent, the DFF was shut down between days 210 and 212 and again between days 217 and 231. To correct the condition of low pH, sodium bicarbonate was added directly to the reactor on day 220. More will be said regarding this upset condition in Section 9.1.

7.3 Modified BVF Operations

Operation of the modified BVF remained similar to that of the DFF as the treatability of the peat pressate waste was assessed. During the entire study, the feeds to the BVF and DFF were identical in waste characteristics. Once again, the loading to the BVF was gradually increased and its performance monitored continuously. The BVF was gently agitated by shaking the model by hand, once daily, five days per week.

The loading to the reactor was gradually increased to 0.71 kg BOD/m^3.d (2.1 kg COD/m^3.d) by increasing the feed rate. The effluent recycle (to feed) ratio was set at 1:1 on day 57 and was maintained at this value until the end of the study. The same supplements were added to the feed as in the operation of the DFF, these being documented in Table 7.3.

7.4 Aerated Pond Operations

The aerated pond was started up on day 140 and was operated until day 217 in the complete-mix mode. As was previously stated, the aerated pond had a detention time of ten days and received BVF effluent as its feed. The pond was seeded with mixed liquor from an aerated pond used in a previous study, involving potato waste. The performance of the aerated pond was monitored on a regular basis, although not as extensively as the DFF and BVF.

7.5 Analyses

In order to monitor the performance of the DFF, BVF and aerated pond, daily grab samples of feed and effluent, from each reactor, were collected and combined to form five-day composites. These samples were refrigerated until analyzed. The composites were analyzed for COD, SS, VSS and BOD. Concentrations of total phosphorus, total Kjeldahl nitrogen (TKN) and ammoniacal nitrogen (NH_3-N) were determined on the BVF and DFF influent and effluent samples on a monthly basis; the concentration of ammoniacal nitrogen was determined on the aerated pond effluent on a monthly basis, also. In addition, grab samples of BVF and DFF influents and effluents were analyzed twice weekly for pH, VA and alkalinity. Total sulfide tests were done once per week on grab samples of feed and BVF and DFF effluents. The pH of the aeration cell was monitored weekly. A complete frequency schedule for all testing is included in Table 7.4.

Biogas production was measured for each reactor in the manner described in Section 6.5. Samples were analyzed weekly for CO_2 (+ H_2S) and O_2, using an ORSAT apparatus, and H_2S separately. Nitrogen was determined by calculation based on the concentration of oxygen in the sample and the ratio of oxygen and nitrogen in air. Methane was determined by difference. The quantities of gases other than CO_2, H_2S, O_2, N_2 and CH_4 were assumed to be negligible.

Upon receipt of each new shipment of peat pressate (three in all), a sample was taken and subjected to a more complete analysis. The results of these analyses are presented in Table 5.2.

A complete list of analytical tests and procedures used in this study is furnished in Table 7.5.

TABLE 7.1 - DFF MODEL OPERATIONS

Day	Event
1 (November 30, 1983)	Reactor started up using 10 percent black liquor as feed; T = 25°C; BOD/N/P ratio set at 200/5/1; loading @ 0.1 kg BOD/m^3.d; HRT = 46 d.
14	Loading @ 0.2 kg BOD/m^3.d; HRT = 23 d.
21	Loading @ 0.3 kg BOD/m^3.d; HRT = 15.3 d.
31	Loading @ 0.4 kg BOD/m^3.d; HRT = 11.5 d.
42	Loading @ 0.5 kg BOD/m^3.d; HRT = 9.2 d.
49	Loading @ 0.6 kg BOD/m^3.d; HRT = 7.7 d.
57	Loading @ 0.7 kg BOD/m^3.d; HRT = 6.3 d; effluent recycle set at 1/1; sludge recycled once daily.
63	Loading @ 0.8 kg BOD/m^3.d; HRT = 5.5 d.
70	Loading @ 0.9 kg BOD/m^3.d; HRT = 4.9 d.
77	Loading @ 1.0 kg BOD/m^3.d; HRT = 4.4 d.
84	Loading @ 1.1 kg BOD/m^3.d; HRT = 4.0 d.
87	Reactor transferred to 35°C room.
91	Loading @ 1.2 kg BOD/m^3.d; HRT = 3.7 d.
98	Loading @ 1.3 kg BOD/m^3.d; HRT = 3.4 d.
105	Loading @ 1.4 kg BOD/m^3.d; HRT = 3.1 d.
107	First shipment of peat pressate received; feed strength set at 25 percent; $NaHCO_3$ added @ 3 g/L.
110	Feed strength set at 50 percent.
112	Loading @ 0.4 kg BOD/m^3.d; HRT = 3.5 d.
119	Model operating on 100 percent peat pressate waste; $NaHCO_3$ dosage set @ 2 g/L.
125	$NaHCO_3$ addition stopped.
127	New shipment of peat pressate received.
133	Loading @ 0.53 kg BOD/m^3.d; HRT = 6.8 d.
140	Yeast extract added @ 0.5 g/L; $NaHCO_3$ added at 2.0 g/L.

TABLE 7.1 - DFF MODEL OPERATIONS (continued)

Day	Event
146	NH_4Cl addition stopped; feed pH adjusted to 6.0-6.5 with NaOH.
148	Effluent recycle set at 5/1.
153	Effluent recycle set at 3/1.
154	Loading @ 0.82 kg BOD/m^3.d; HRT = 6.0 d.
160	Feed pH adjusted to 5.5-6.0 with NaOH; recycle set @ 2/1.
161	Loading @ 0.87 kg BOD/m^3.d; HRT = 5.3 d.
168	Loading @ 1.20 kg BOD/m3.d; HRT = 3.9 d.
175	Yeast extract addition stopped; feed pH adjusted to 4.5-5.0 with NaOH.
182	Loading @ 1.68 kg BOD/m^3.d; HRT = 2.7 d.
188	Feed pH adjusted to 3.50-4.0 with NaOH.
189	Loading @ 2.20 kg BOD/m^3.d; HRT = 2.3 d.
196	New shipment of peat pressate received; no feed pH adjustment; loading @ 2.47 kg BOD/m^3.d; HRT = 1.6 d.
203	Loading @ 2.08 kg BOD/m^3.d; HRT = 1.57 d.
210	Reactor shut down.
212	Reactor started up; loading @ 1.83 kg BOD/m3.d; HRT = 1.75 d.
217	Reactor shut down.
220	23 g $NaHCO_3$ added to reactor to adjust the pH to approximately 8.0.
231	Reactor started up; loading @ 0.69 kg BOD/m3.d; HRT = 4.8 d; feed pH adjusted to 6.0 with NaOH.
238	Loading @ 1.34 kg BOD/m3.d; HRT = 3.8 d.
245 (July 30, 1984)	Reactor shut down.

TABLE 7.2 - CHARACTERISTICS OF BLACK LIQUOR(1)

Test	Result(2)
COD	150 000
BOD	31 500
pH	9.24
Alk	28 900
VA	29 390
TKN	385
NH_3-N	1.0
TOTAL P	53.0
SS	24 755
VSS	17 411
TS	222 250
TVS	81 064
TOTAL Sulfur	543
SO_4	208
SO_3	342
Sulfide (total)	101
Sulfide (soluble)	0
Na	25 100

Notes: 1. before dilution

2. results expressed in mg/L except for pH

TABLE 7.3 - BVF OPERATIONS

Day	Event
41 (January 9, 1984)	Seed acclimation started in a "bucket" reactor using 10 percent black liquor as feed; loading @ 0.1 kg BOD/m^3.d; BOD/N/P ratio set at 200/5/1; T = 25°C.
43	Additional seed sludge added to model.
49	Loading @ 0.2 kg BOD/m^3.d.
57	Loading @ 0.3 kg BOD/m3.d; contents of "bucket" reactor transferred to BVF; effluent recycle set at 1:1; sludge recycle set at 5 min/day.
63	Loading @ 0.4 kg BOD/m^3.d.
77	Loading @ 0.3 kg BOD/m^3.d.
87	BVF moved to 35°C room; 1 L food processing sludge added to BVF.
98	Loading @ 0.4 kg BOD/m3.d.
105	Began slow agitation of model once daily, five days per week.
107	First shipment of peat pressate received; model begins operation on peat pressate waste; feed strength set at 25 percent; loading @ 0.2 kg COD/m^3.d.
110	Feed strength set at 50 percent.
118	Loading @ 0.14 kg BOD/m^3.d; HRT = 10.3 d.
119	Model operating on 100 percent peat pressate waste.
125	$NaHCO_3$ addition dropped.
127	New shipment of peat pressate received.
132	Loading @ 0.19 kg BOD/m^3.d; HRT = 13.4 d.
140	Yeast extract added @ 0.5 g/L; $NaHCO_3$ added @ 2 g/L; NH_4Cl addition stopped.
146	Feed pH adjusted NaOH to 6.0-6.5.
160	Loading @ 0.33 kg BOD/m^3.d; HRT = 13.7 d.

TABLE 7.3 - BVF OPERATIONS (continued)

Day	Event
175	Loading @ 0.39 kg BOD/m^3.d; HRT = 11.2 d; yeast extract addition stopped; feed pH adjusted to 4.5 using NaOH.
181	Loading @ 0.56 kg BOD/m^3.d; HRT = 7.1 d.
188	Loading @ 0.65 kg BOD/m^3.d; HRT = 6.7 d; feed pH adjusted to 3.5-4.0 with NaOH.
195	Loading @ 0.70 kg BOD/m^3.d; HRT = 6.7 d.
196	New shipment of peat pressate received; no feed pH adjustment.
209	Loading @ 0.71 kg BOD/m^3.d; HRT = 4.7 d.
217 (July 3, 1984)	Reactor shut down.

TABLE 7.4 - ANALYTICAL TEST/FREQUENCY SCHEDULE

Test	Downflow Filter			BVF			Aerated Pond
	Influent	Effluent	Biogas	Influent	Effluent	Biogas	
Temp		D			D		
pH	T	T		T	T		W
BOD	W	W		W	W		M
COD	W	W		W	W		W
SS	W	W		W	W		W
VSS	W	W		W	W		W
VA	T	T		T	T		
ALK	T	T		T	T		
NH_3-N	M	M		M	M		M
TKN	M	M		M	M		
TOT-P	M	M		M	M		
S^{2-} (Total)	W	W		W	W		
CH_4			W			W	
CO_2			W			W	
H_2S			W			W	

D = daily, T = twice weekly
W = weekly, M = monthly

Notes: influents are the same

TABLE 7.5 - ANALYTICAL PROCEDURES

Parameter	Procedure
BOD	Standard Methods (14)
COD	Dichromate Digestion, Hach
SS	Standard Methods (14)
VSS	Standard Methods (14)
TS	Standard Methods (14)
TVS	Standard Methods (14)
TKN	Standard Methods (14)
NH_3-N	Standard Methods (14)
Total Phosphorus	Standard Methods (14)
Total Sulfur	TAPPI Standard Method (15)
SO_4	Standard Methods (14)
Sulphide	Standard Methods (14)
Alkalinity	Standard Methods (14)
VA (ADI)	See Reference (16)
VA (NRC)	See Reference (17)
Ca	Standard Methods (14)
Cd	Atomic Absorption (AA)
Co	AA
Cr	AA
Cu	AA
Fe	AA
K	AA
Mg	AA
Na	AA
Ni	AA
Pb	AA
Se	AA
Zn	AA
Hg	Standard Methods (14)
Gas - CO_2 ($+H_2S$)	ORSAT, (see reference 18)
Gas - H_2S	MSA apparatus (Samplair Pump and H_2S tubes)
Furfural	Procedure outlined in reference (19)

8.0 RESULTS

The performance of the DFF and modified BVF were monitored throughout this study as the organic loading was progressively increased. The routine analytical tests done on each model and the frequency of testing were shown in Table 7.4 and discussed in the previous section.

It should be pointed out that the data presented here may not truly reflect steady-state performance or conditions. Normally, at least two to three weeks are required for a model to stabilize after operating conditions have been changed to any degree; however, time limitations did not permit this luxury here. Experience from similar treatability studies has demonstrated that data collected under such conditions, normally, can be used to project steady-state operating performance.

The VA test used by ADI is a titration method[16] and is subject to different interferences. Recent experience has shown that this method gives erroneous and inconsistent results on several wastewaters. This was the case here, the titration method giving significantly higher results than those obtained by gas chromatographic methods[17] used at the NRCC Biological Sciences Laboratory in Ottawa. Table 8.1 shows a comparison of VA test results by both NRC and ADI. See Section 9.5 for additional discussion.

8.1 Downflow Filter

The figures listed below are a graphical presentation of the temporal variation of the respective parameters and can be found at the end of Section 8.

Figure 8.1 - COD Loadings, Concentrations and Removals
Figure 8.2 - BOD Loadings, Concentrations and Removals
Figure 8.3 - SS and VSS Concentrations
Figure 8.4 - VA Concentrations
Figure 8.5 - pH and Alkalinity

Tables 8.2, 8.3, 8.4, 8.5 and 8.6 present Nitrogen (NH_3 and TKN), Total Sulfide, Suspended Solids, Chemical Dosages for Feed pH Adjustment and Specific Methane Generation and Gas Composition Data from the DFF operations, respectively. These tables are located at the rear of this section.

The results indicate that COD/BOD removals in the range of 60-70 percent/80-90 percent can be obtained in the DFF.

While the SS data were very erratic, resulting from large swings in feed SS concentrations, decreasing HRT, changes in effluent recycle rates, biogas mixing, etc., the DFF did achieve an average SS removal of approximately 40 percent during the study.

On day 210, while at a COD loading of approximately 5.0, the reactor was shut down due to rising VA and failing performance. The unit was restarted after a two-day rest and after the VA level had fallen to less than 500 mg/L. On day 217, the model was again shut down (until day 231) when the VA was again high (and rising) and the reactor pH had fallen below 6.0. This upset condition and period of instability is believed to be the

result of insufficient levels of alkalinity for proper pH control. Alkalinity levels were being deliberately lowered at this time in an effort to reduce chemical dosage, for pH control, to more realistic levels (reference Table 8.5).

The specific methane generation rate for the DFF averaged approximately 0.31 m^3CH_4/kg COD destroyed, which is 90 percent of the theoretical value. The methane content of the biogas varied throughout the study, ranging from 50.4 to 83.7 percent.

8.2 Modified BVF

The temporal variations of COD, BOD, SS and VSS, VA and pH and Alkalinity, for the BVF operations, are shown in Figures 8.6, 8.7, 8.8, 8.9 and 8.10, respectively. These figures appear at the end of Section 8.

Tables 8.2, 8.3, 8.5, 8.7 and 8.8 present TKN and Ammonia, Total Sulfide, Chemical Dosages for Feed pH Adjustment, SS and VSS and Specific Methane Generation and Gas Composition Data, respectively, for the BVF. These tables also appear at the end of Section 8.

The BVF performance results indicate that COD and BOD removals of at least 60 and 80 percent, respectively, can be expected. The upper practical limit of COD and BOD removal appears to be in the 70 percent and 90 percent range, respectively.

The average SS removal for the duration of the study was approximately 30 percent. The individual weekly removals were erratic, as was the case for the DFF.

The general overall performance of the BVF was quite satisfactory, and it would appear that for the loadings studied, the reactor could operate without addition of chemicals for pH control.

8.3 Aerated Pond

The parameters monitored on the aerated pond (AP) effluent were pH, COD, BOD, SS, VSS and NH_3. These parameters, with the exception of VSS, are presented in Table 8.9 for both the AP influent and effluent. As stated previously, the influent to the AP was BVF effluent.

The AP was operated at room temperature throughout the study and gave good performance, both in terms of BOD and ammonia removal.

TABLE 8.1 - COMPARISON OF VA ANALYSES DONE BY NRCC AND ADI

Sample	Volatile Acids Expressed as mg/L Acetic Acid	
	ADI	NRC
Feed	3630	913
Feed	1756	340
Feed	3161	1667
Feed	2070	340
DFF Effluent	690	70
DFF Effluent	1368	777
DFF Effluent	858	90
DFF Effluent	361	50
DFF Effluent	2130	1293
BVF Effluent	706	60
BVF Effluent	718	70
BVF Effluent	783	310
BVF Effluent	660	329

TABLE 8.2 - TKN/AMMONIA NITROGEN CONCENTRATIONS

DATE	DFF		BVF		AP
	INF	EFF	INF	EFF	EFF
84/4/3-9	486/268	343/245	486/268	277/169	
84/5/1-7	558/271	459/275	558/271	399/254	--/14.4
84/5/29-6/4	446/230	368/250	446/230	372/239	--/ 6.8
84/6/26-7/3	369/179	/240	369/179	339/207	--/ 8.5
84/7/24-30	361/168	370/219	361/168	---	
Average	444/223	385/246	444/223	347/217	--/ 9.9

Notes: 1. All results expressed as mg/L.

2. TKN/Ammonia values

3. BVF Eff. = AP Inf.

TABLE 8.3 - TOTAL SULFIDE CONCENTRATIONS

Date	Influent	DFF Effluent	BVF Effluent
84/4/2	0.40	8.4	8.4
84/4/9	0.08	19.4	13.7
84/4/16	1.1	24.0	18.1
84/5/7	0	0.3	0
84/5/28	0	0.67	0
84/6/4	0	0	0
84/6/18	0	0	0
84/6/25	0	0	1.0

TABLE 8.4 - DFF - SUSPENDED SOLIDS AND VOLATILE SUSPENDED SOLIDS DATA

DATE	Feed Volume (L)	Influent SS (mg/L)	Influent SS (g)	Influent VSS (mg/L)	Influent VSS (g)	Effluent SS (mg/L)	Effluent SS (g)	Effluent VSS (mg/L)	Effluent VSS (g)
84/3/15-19	2.6	175	0.5	121	0.3	42	0.1	42	0.1
84/3/19-27	5.5	286	1.6	200	1.1	121	0.7	99	0.6
84/3/27 -84/4/2	2.3	542	1.3	370	0.9	138	0.3	107	0.3
84/4/2-9	2.2	472	1.0	380	0.8	171	0.4	154	0.3
84/4/9-17	2.9	582	1.7	582	1.7	214	0.6	175	0.5
84/4/17-23	2.1	427	0.9	328	0.7	131	0.3	131	0.3
84/4/24-30	2.3	609	1.4	494	1.1	424	1.0	324	0.8
84/4/30 -84/5/7	2.8	878	2.5	586	1.6	320	0.9	228	0.6
84/5/7-15	3.4	438	1.5	352	1.2	158	0.5	121	0.4
84/5/15-22	4.4	986	4.3	586	2.6	200	0.9	148	0.7
84/5/22-28	3.8	692	2.6	450	1.7	583	2.2	388	1.5
84/5/28 -84/6/5	6.7	554	3.7	412	2.8	256	1.7	206	1.4
84/6/5-12	7.3	556	4.1	406	3.0	205	1.5	165	1.2
84/6/12-19	9.5	357	3.4	296	2.8	417	4.0	354	3.4
84/6/19-26	9.9	533	5.3	403	4.0	298	3.0	238	2.4
84/6/28 -84/7/3	6.0	622	3.7	462	2.8	328	2.0	262	1.6
84/7/17-24	3.1	404	1.3	404	1.3	709	2.2	709	2.2
84/7/24-30	5.4	635	3.4	418	2.3	420	2.3	307	1.7
TOTALS			44.2		32.7		24.6		20.1

TABLE 8.5 - CHEMICAL DOSAGES REQUIRED FOR FEED pH ADJUSTMENT

Date	Initial pH	Final pH	NaOH Dosage (g/L)	$NaHCO_3$ Dosage (g/L)
84/3/27	3.42	5.29	--	2.0
84/4/2	3.50	3.50	--	--
84/4/9	3.20	3.20	--	--
84/4/17	3.28	3.95	--	2.0
84/4/23	3.10	7.70	3.45	--
84/4/30	3.30	6.00	--	6.9
84/5/7	3.20	5.60	2.77	--
84/5/15	3.00	5.60	2.83	--
84/5/22	2.80	4.50	2.30	--
84/5/28	3.12	4.38	1.91	--
84/6/4	2.79	3.50	1.17	--
84/6/12	3.40	3.40	--	--
84/6/19	3.25	3.25	--	--
84/6/26	3.70	3.70	--	--
	Model Shut Down June 26-28 and July 3-17			
84/7/17	3.20	6.00	1.58	--
84/7/23	3.10	6.60	1.76	--

TABLE 8.6 - DFF - SPECIFIC METHANE GENERATION AND GAS COMPOSITION DATA

Date	COD Loading ($kg/m^3.d$)	Specific Methane Generation Rate m^3/kg COD removed (STP)	% CH_4 (by volume)	% CO_2 (by volume)	% O_2 (by volume)	% N_2 (calculated)	H_2S (ppm)
84/3/20-26	1.23	0.26	82.8	14.8	0.5	1.9	11
84/3/27-4/2	1.20	0.23	83.7	13.4	0.6	2.3	10
84/4/2-9	1.10	0.36	65.2	30.5	0.9	3.4	0
84/4/9-17	1.78	0.25	55.7	40.3	0.7	3.3	23
84/4/17-23	1.59	0.36	65.1	33.0	0.4	1.5	16
84/4/24-30	1.95	0.31	78.9	18.2	0.6	2.3	12
84/4/30-5/7	1.89	0.46	77.9	18.3	0.8	3.0	10
84/5/7-15	2.17	0.36	79.2	19.4	0.3	1.1	18
84/5/15-22	4.5	0.18	77.5	21.5	0.2	0.8	29
84/5/22-28	3.32	0.27	70.2	27.9	0.4	1.5	52
84/5/28-6/5	4.21	0.28	63.0	37.0	0	0	0
84/6/5-12	5.5	0.28	56.7	42.8	0.1	0.4	0
84/6/12-19	6.09	0.52	50.4	46.8	0.6	2.2	32
84/6/19-26	6.3	0.28	53.1	46.9	0	0	99
84/6/26-7/3	5.1	0.22	53.5	46.5	0	0	547
84/7/17-24	1.96	0.48	69.5	25.3	1.1	4.1	533
84/7/24-30	4.11	0.24	65.0	35.0	0.0	0.0	-
Average		0.314					

TABLE 8.7 - BVF - SUSPENDED SOLIDS AND VOLATILE SUSPENDED SOLIDS DATA

DATE	Feed Volume (L)	Influent SS (mg/L)	Influent SS (g)	Influent VSS (mg/L)	Influent VSS (g)	Effluent SS (mg/L)	Effluent SS (g)	Effluent VSS (mg/L)	Effluent VSS (g)
84/3/15-19	2.6	175	0.5	121	0.3	140	0.4	135	0.4
84/3/19-27	5.2	286	1.5	200	1.0	201	1.1	168	0.9
84/3/27 -84/4/2	2.2	542	1.2	370	0.8	552	1.2	426	0.9
84/4/2-9	3.4	472	1.6	380	1.3	344	1.2	288	1.0
84/4/9-17	3.4	582	2.0	582	2.0	721	2.5	484	1.7
84/4/17-23	2.7	427	1.2	328	0.9	621	1.7	465	1.3
84/4/24-30	4.0	609	2.4	494	2.0	217	0.9	193	0.8
84/4/30 -84/5/7	3.4	878	3.0	586	2.0	138	0.5	114	0.4
84/5/7-15	4.1	438	1.8	352	1.4	169	0.7	113	0.5
84/5/15-22	4.3	986	4.2	586	2.5	169	0.7	135	0.6
84/5/22-28	5.7	692	3.9	450	2.6	134	0.8	102	0.6
84/5/28 -84/6/5	7.5	554	4.2	412	3.1	328	2.5	204	1.5
84/6/5-12	7.0	556	3.9	406	2.8	216	1.5	160	1.1
84/6/12-19	8.3	357	3.0	296	2.5	671	5.6	574	4.8
84/6/19-26	10.1	533	5.4	403	4.1	572	5.8	458	4.6
84/6/26 -84/7/3	5.5	622	3.4	462	2.5	376	2.1	288	1.6
TOTALS			43.2		31.8		29.2		22.7

TABLE 8.8 - BVF - SPECIFIC METHANE GENERATION AND GAS COMPOSITION DATA

Date	COD Loading ($kg/m^3.d$)	Specific Methane Generation Rate m^3/kg COD removed (STP)	% CH_4 (by volume)	% CO_2 (by volume)	% O_2 (by volume)	% N_2 (calculated)	H_2S (ppm)
84/3/20-26	0.42	0.57	81.8	14.4	0.8	3.0	26
84/3/26-4/2	0.45	0.39	82.6	14.5	0.6	2.3	14
84/4/2-9	0.60	0.32	59.2	29.4	2.4	9.0	17
84/4/9-17	0.68	0.29	53.0	45.1	0.4	1.5	41
84/4/17-23	0.67	0.39	59.5	40.5	0	0	35
84/4/24-30	1.10	0.30	71.7	26.9	0.3	1.1	55
84/4/30-5/7	0.76	0.47	76.2	20.0	0.8	3.0	54
84/5/7-15	0.84	0.32	74.1	23.5	0.5	1.9	47
84/5/15-22	1.45	0.22	75.5	22.6	0.4	1.5	45
84/5/22-28	1.63	0.27	67.4	31.6	0.2	0.8	132
84/5/28-6/5	1.62	0.28	65.0	35.0	0	0	-
84/6/5-12	1.72	0.35	60.8	36.8	0.5	1.9	100
84/6/12-19	1.79	0.30	48.7	43.2	1.7	6.4	18
84/6/19-26	2.15	0.34	57.6	42.4	0	0	100
84/6/26-7/3	1.08	0.58	87.5	12.5	0	0	391
Average		0.359					

TABLE 8.9 - AERATED POND ANALYSES

Date	COD, mg/L		BOD, mg/L		pH		SS, mg/L		NH_3-N, mg/L	
	INF	EFF	INF	EFF	INF	EFF	INF	EFF	INF	EFF
84/4/17-23	3950	450	360	39	7.10	9.10	621	206		
84/4/24-30	4300	1420			8.30	9.00	217	56		
84/5/1-7	3800	2000	616	36	8.38	8.78	138	47	254	14.4
84/5/8-14	4150	2900			8.40	9.40	169	59		
84/5/15-22	4200	3400	469	65	8.40	9.10	169	53		
84/5/22-28	4200	3200			8.17	9.24	134	43		
84/5/29-6/4	4000	3300	551	39	8.15	9.17			239	6.8
84/6/5-11	4400	4400			7.70	8.90	216	46		
84/6/12-18	4000	3700			7.71	9.04	671	55		
84/6/19-25	4000	3300	705	37	7.29	8.70	572	94		
84/6/26-7/3	4000	2700	612	48	8.10		376	82	207	8.5
Average Results	4091	2797	552	44			328	74	233	9.9

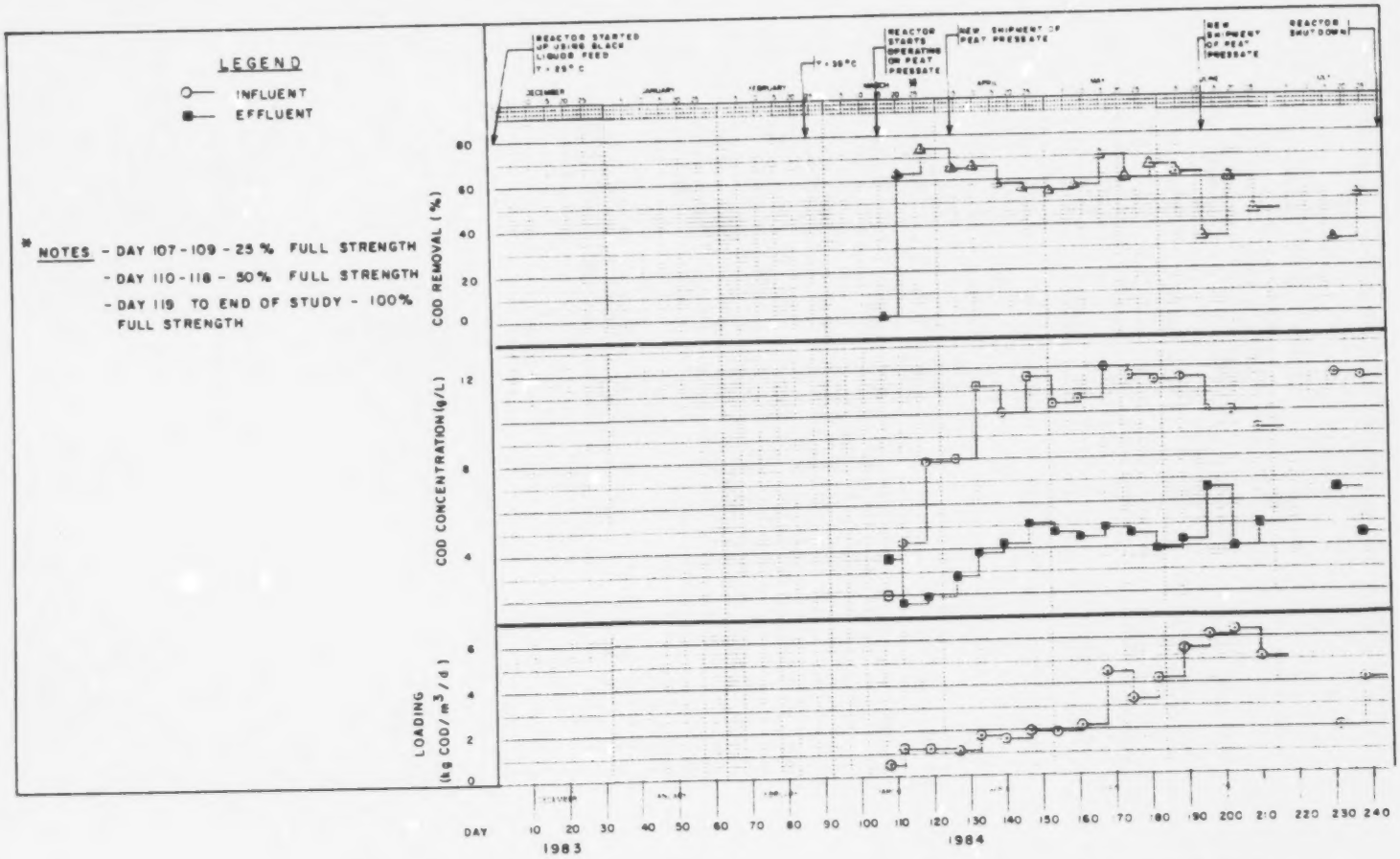

LEGEND
INFLUENT
EFFLUENT
* NOTES - DAY 107 - 109 - 25 % FULL STRENGTH
- DAY 110 - 118 - 50% FULL STRENGTH
- DAY 119 TO END OF STUDY - 100% FULL STRENGTH
REACTOR STARTED UP USING BLACK LIQUOR FEED T = 25° C
T = 35°C
REACTOR STARTS OPERATING ON PEAT PRESSATE
NEW SHIPMENT OF PEAT PRESSATE
NEW SHIPMENT OF PEAT PRESSATE
REACTOR SHUT DOWN
COD REMOVAL (%)
COD CONCENTRATION (g/L)
LOADING (kg COD/m3/d)
DAY
1983
1984

FIGURE 8.1 : GEOTEXTILE MEDIA DFF COD LOADINGS, CONCENTRATIONS & REMOVALS

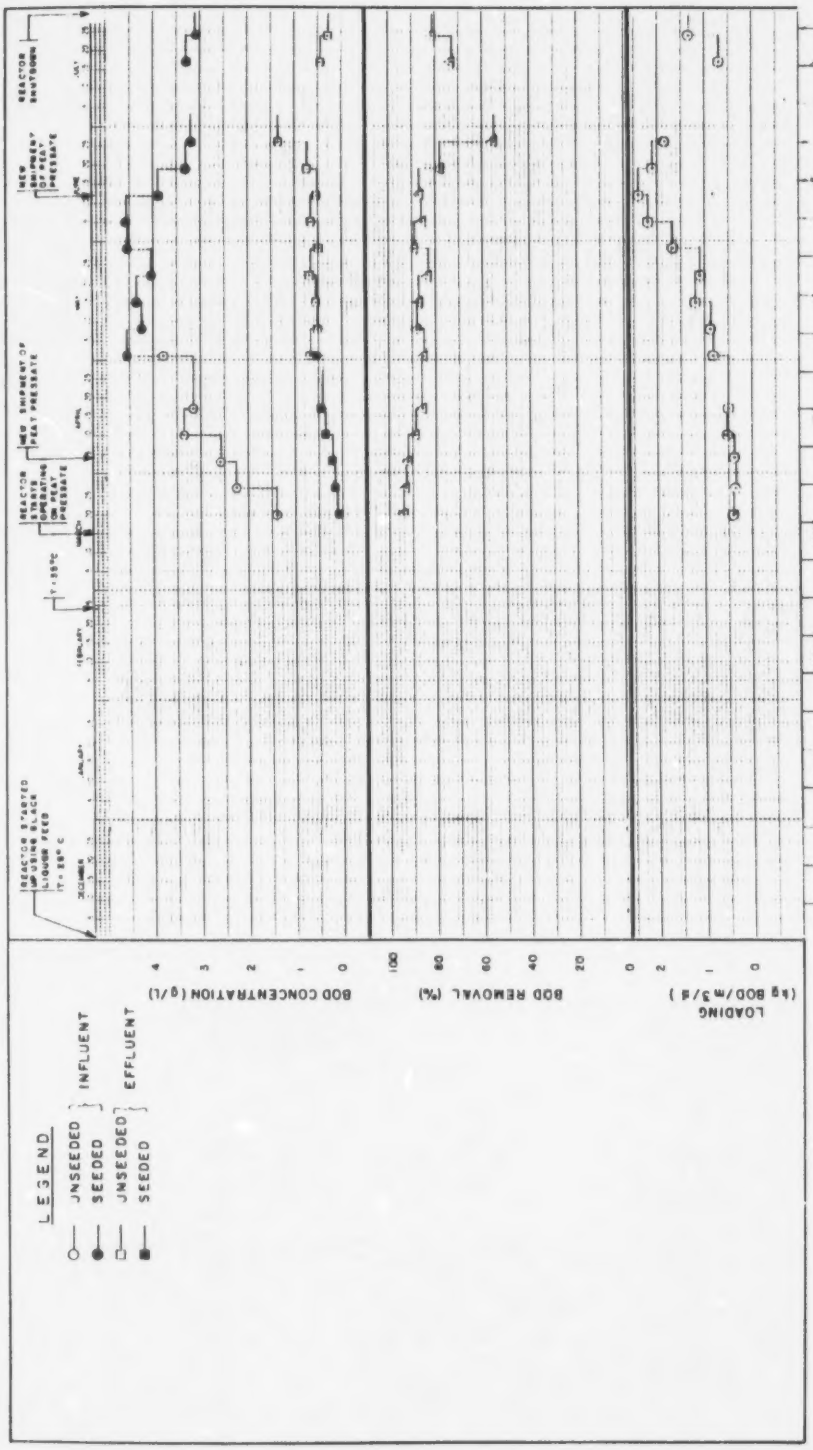


FIGURE 8.2 : GEOTEXTILE MEDIA DFF BOD LOADINGS, CONCENTRATIONS & REMOVALS

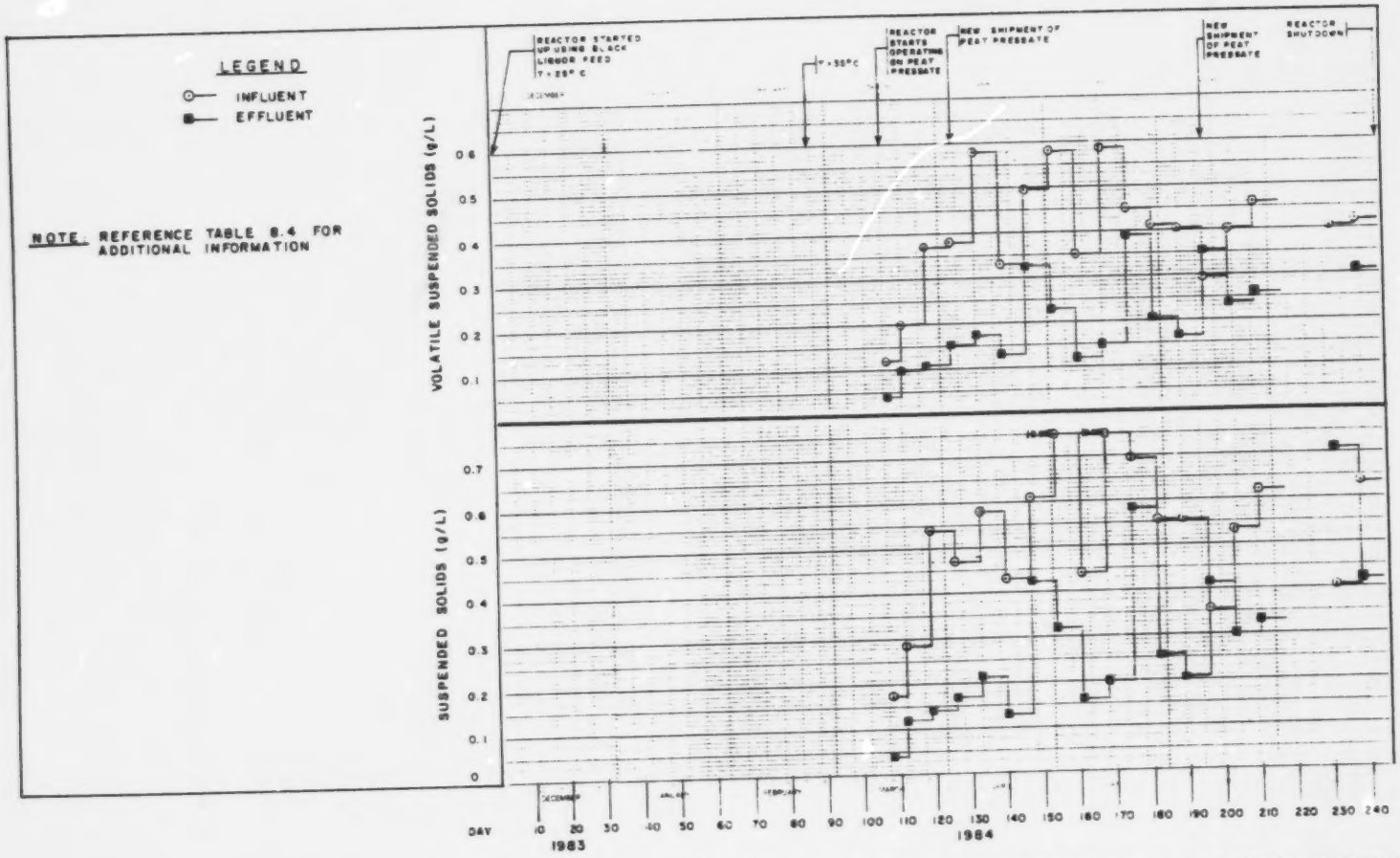


FIGURE 8.3 : GEOTEXTILE MEDIA DFF SUSPENDED AND VOLATILE SUSPENDED SOLIDS CONCENTRATIONS

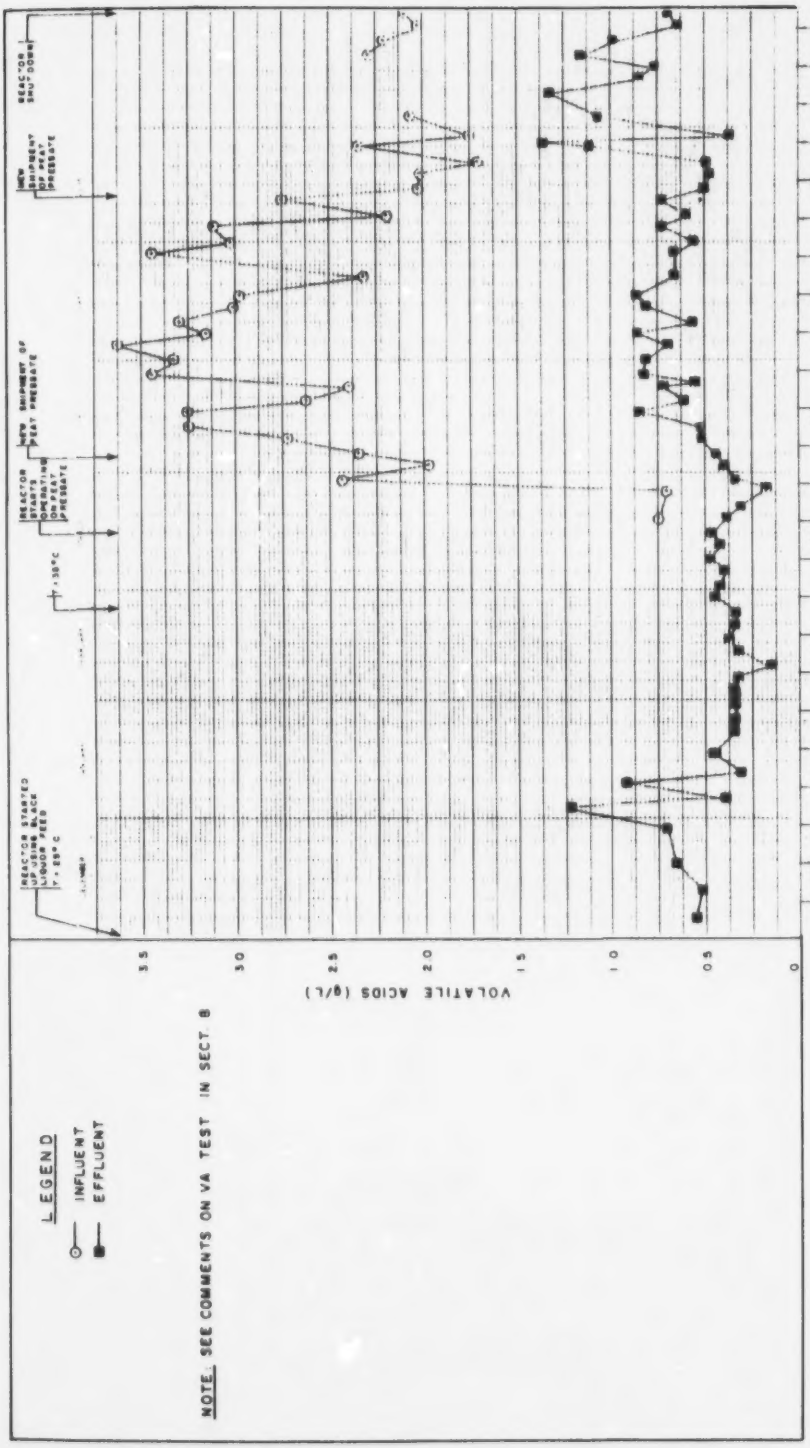


FIGURE 8.4 : GEOTEXTILE MEDIA DFF VOLATILE ACIDS CONCENTRATIONS

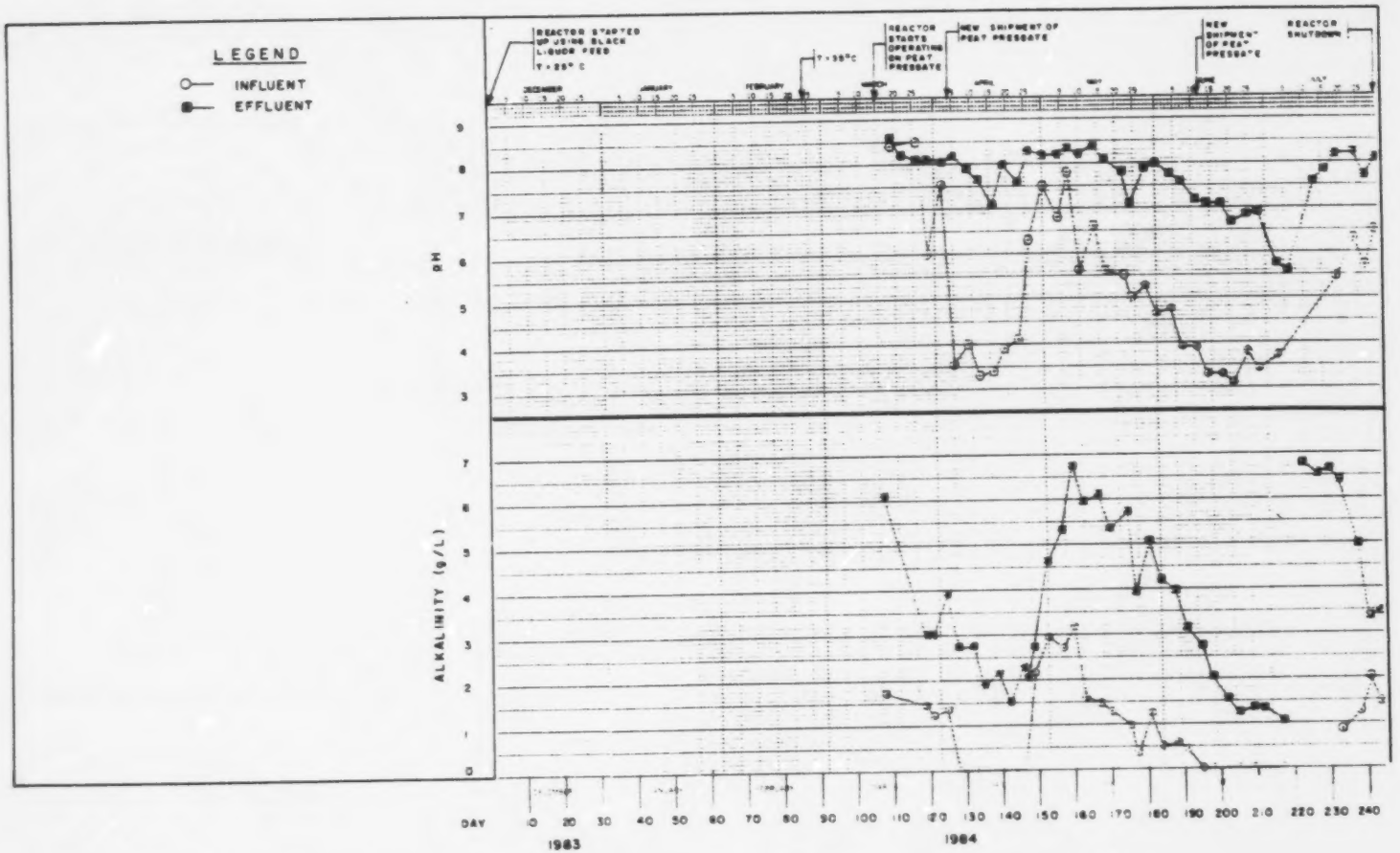


FIGURE 8.5 : GEOTEXTILE MEDIA DFF pH & ALKALINITY CONCENTRATIONS

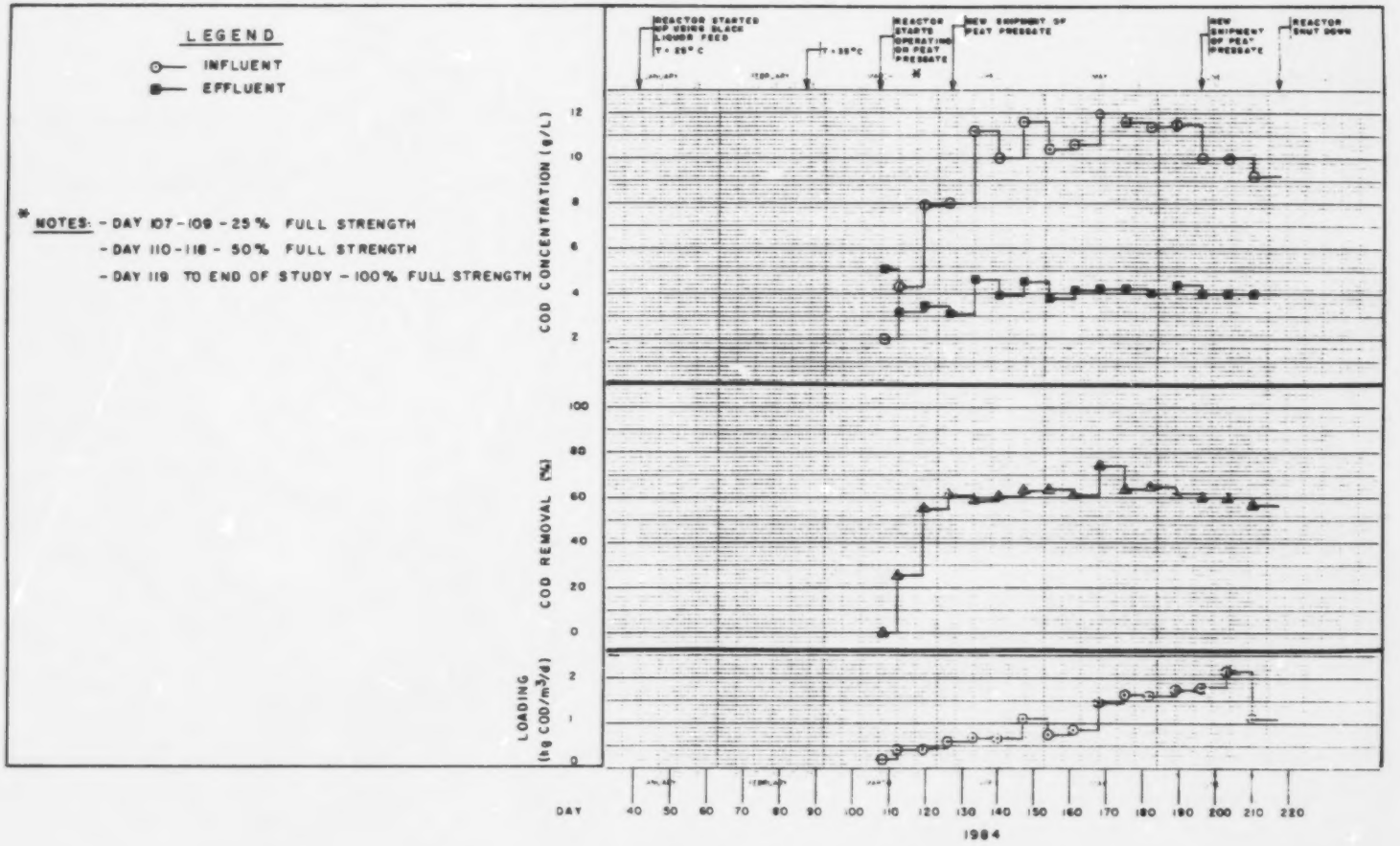

LEGEND
INFLUENT
EFFLUENT
* NOTES: - DAY 107 - 109 - 25 % FULL STRENGTH
- DAY 110 - 118 - 50 % FULL STRENGTH
- DAY 119 TO END OF STUDY - 100 % FULL STRENGTH
REACTOR STARTED UP USING BLACK LIQUOR FEED
T = 25° C
REACTOR STARTS OPERATING ON PEAT PRESSATE
NEW SHIPMENT OF PEAT PRESSATE
NEW SHIPMENT OF PEAT PRESSATE
REACTOR SHUT DOWN
COD CONCENTRATION (g/L)
COD REMOVAL (%)
LOADING (kg COD/m³/d)
DAY
1984

FIGURE 8.6 : BVF COD LOADINGS, CONCENTRATIONS & REMOVALS

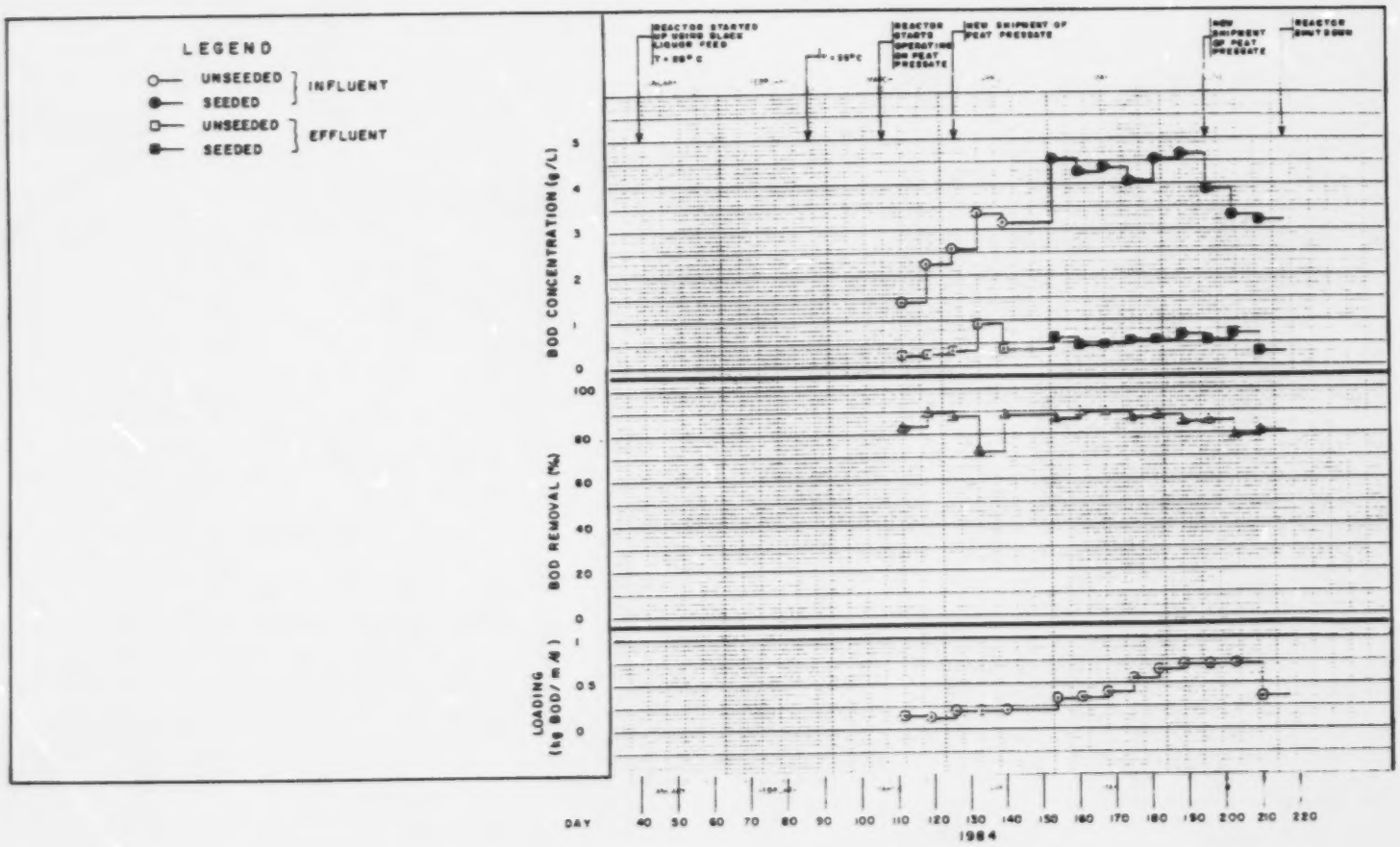


FIGURE 8.7 : BVF BOD LOADINGS, CONCENTRATIONS & REMOVALS

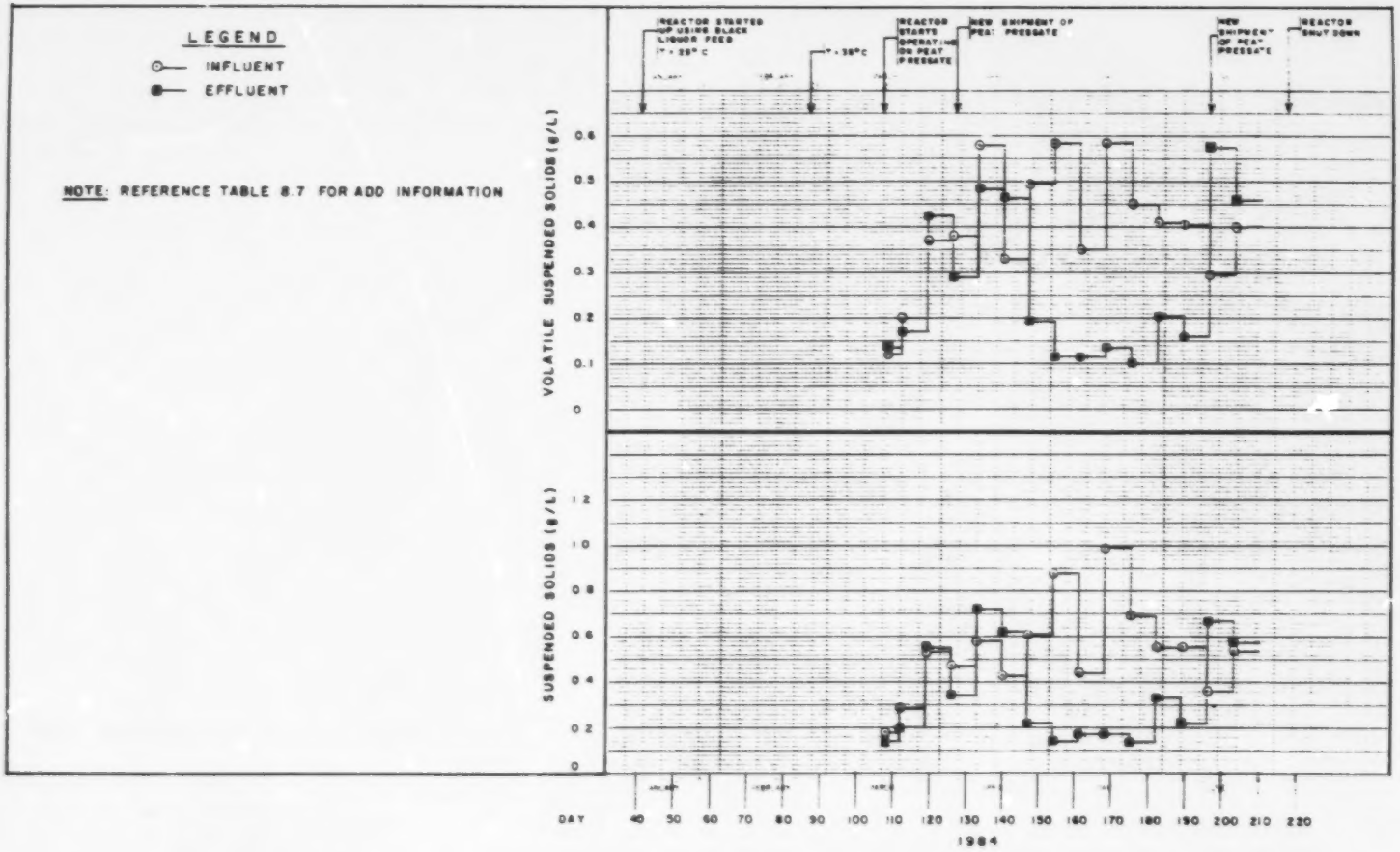


FIGURE 8.8 : BVF SUSPENDED AND VOLATILE SUSPENDED SOLIDS CONCENTRATIONS

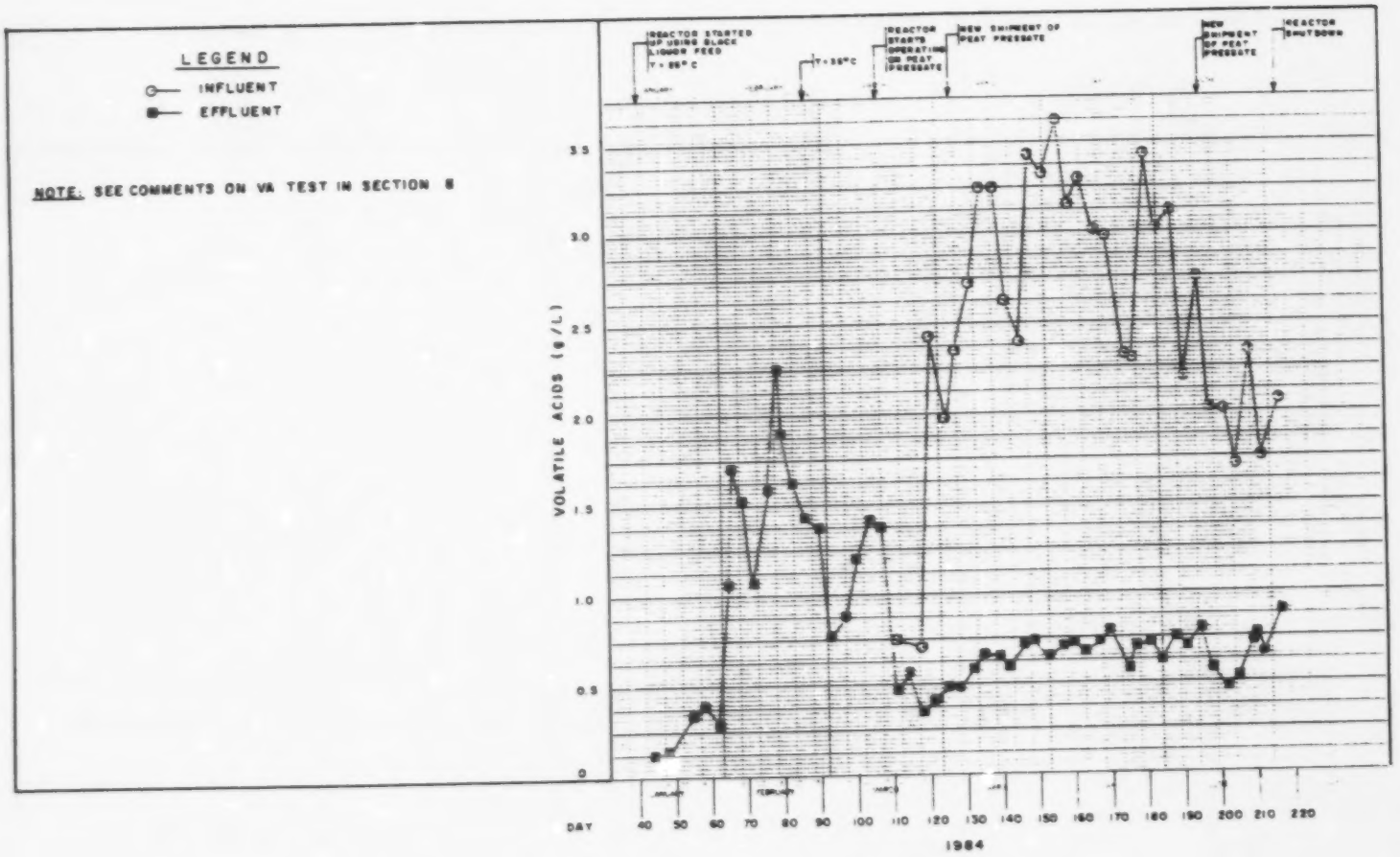


FIGURE 8.9 : BVF VOLATILE ACIDS CONCENTRATIONS

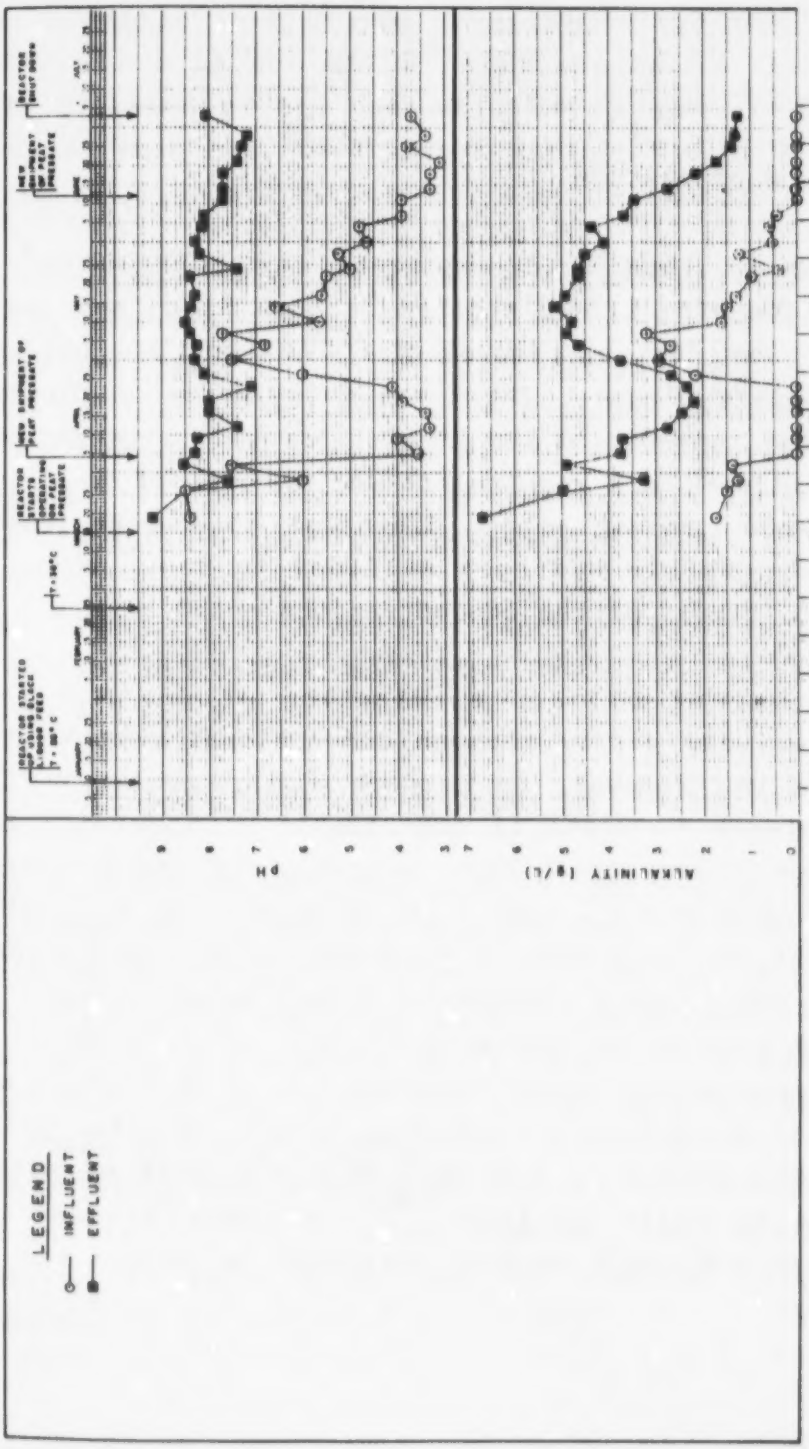


FIGURE 8.10 : BVF pH & ALKALINITY CONCENTRATIONS

9.0 DISCUSSION OF RESULTS

The findings of this study indicate that ORF WETOX^R peat pressate can be effectively treated in both high- and low-rate anaerobic systems for the removal of COD/BOD and the production of a high-quality biogas. There was no evidence of biological toxicity at any time during the study. Aerobic polishing of the anaerobic effluent is a requirement for removal of NH_3 and H_2S and further BOD removal before discharge to the environment. Ammonia (and possibly hydrogen sulfide) is known to be very toxic to fish (trout) at the concentrations noted here.

Further removal of BOD and elimination of any H_2S can be obtained relatively easily through conventional aerobic treatment. While NH_3 removal, to produce a high-quality effluent which is nontoxic to fish, is conceivable with aerobic treatment, a system to accomplish this is costly and can be difficult to operate. The difficulties arise because of the sensitivity of the nitrifying bacteria to such environmental factors as temperature, pH, loading, dissolved oxygen levels, etc. Other complications also enter the picture such as an effluent with high NO_3 concentrations (from nitrification of NH_3) which may be problematic if it enters a receiving stream used for drinking water, and the potential presence of quantities of nitrite, which are also toxic to fish.[20] Further discussion on problems associated with aerobic treatment is beyond the scope of this study.

There is little that can be done to control the high ammonia concentration in the WETOX^{R} effluent as it is, to a large extent, dictated by the concentration of peat feed slurry and quality of peat and, to a lesser extent, the WETOX^{R} processing conditions. Pressate recycle may also be a factor.

Data from this study (reference Table 8.2) indicates that pressate ammonia levels are of the order of 200 mg/L and increase very little through the anaerobic reactor. In fact, results on the BVF effluent show a slight decrease in ammonia level. However, this may be due to experimental error. The results of previous work[1] reported ammonia concentrations of 200 to 600 mg/L in the WETOX^{R} pressate effluent.

Further discussion on ammonia (and hydrogen sulfide), as it relates to biological and fish toxicity, is presented in Sections 9.2 and 9.4.

9.1 Performance of DFF and Modified BVF

The performance of both reactors was encouraging throughout the study. Even though the DFF became "upset" at one point in the program, it did respond to "treatment" and was well on its way to full recovery when the study terminated. COD and BOD removals in the range of 60-70 percent and 80-90 percent, respectively, appear to be achievable using either the DFF or BVF. These ranges of removals may change somewhat depending on the characteristics of pressate and conditions under which the anaerobic reactor is operated; however, they should be representative of that which can be expected with anaerobic treatment.

The highest DFF loading achieved during the study was approximately 6 kg COD/m^3.d (2.5 on BOD basis) before the reactor became upset. Experience has shown that DFF reactors are capable of much higher loadings. This is further reinforced by the present study results (for periods when the reactor was not under stress), which show that COD and BOD removals were relatively high and yet only a weak function of loading, over the range of loadings studied. All evidence, including the fact that the BVF was operating on the same waste at the time of upset, suggests that the upset was the result of deliberately lowering the reactor alkalinity which eventually led to low pH.

There is no evidence to support the view that the upset was caused by ammonia or some other toxic chemical, although this cannot be ruled out entirely. In a fully acclimated/mature system, it is unlikely that this upset would have occurred, even at somewhat lower alkalinity levels.

For purposes of developing the costs of a full-scale DFF system, a design loading of 8 kg COD/m^3.d at 60 percent COD removal was assumed. It is expected that once the DFF is fully matured, the VA concentrations in the reactor would be less than 500 mg/L. From experience, noting the minimum ammonia level will be of the order of 200 mg/L, the alkalinity should be at least 1200 mg/L. An alkalinity/VA ratio of 2 or higher is normally adequate to maintain acceptable reactor pH. Therefore, it was assumed that no chemical addition would be necessary after reactor maturation. It is felt that the above DFF loading is reasonable in light of the high loadings achieved with this type of reactor using other wastes; however, a higher loading is not justifiable in light of the experience here and the fact that, for practical reasons, the media SSA for a full-scale system would have to be 30 to 50 percent lower than that used in the model.

The highest BVF loadings achieved here were 2.3 kg COD/m^3.d and 0.7 kg BOD/m^3.d, for which the removals were approximately 60 and 80 percent, respectively. The data plotted in Figures 8.6 and 8.7 reveal that the BVF performance was a weak function of loading. This observation suggests that at least further, marginal increases in loading are possible without significant sacrifice in COD or BOD removals. For purposes of developing full-scale costs, COD and BOD loadings of approximately 1.70 and 0.75 kg/m^3.d, respectively, were assumed.

This study was one of the first extensive studies done using the modified BVF technology. This work has served to verify previous in-house findings that the conventional BVF design loading of 1 kg COD/m^3.d can be doubled and perhaps tripled by operating in the modified mode. This aspect is very significant for it demonstrates that the modified BVF can operate, at least in some cases, at loadings used in anaerobic contact processes. Since the BVF utilizes less costly earthen basin construction and requires no clarifier, it is less costly to build.

The average SS removal in the DFF for the duration of the study was approximately 40 percent. Experience has shown that the SS removal in this type of reactor is not very predictable, as it is affected by such factors as degradability of the suspended solids, wastewater and SS characteristics, physical and process design and mode of operation. The SS removal, as seen from Figure 8.3 and Table 8.4, was erratic throughout the study. Factors which contributed to this behaviour were swings in feed SS concentrations, biomass sloughing, changing recycle ratios, biogas mixing, which would have increased in proportion to loadings, and decreasing HRT. There was some apparent solids accumulation in the DFF; this aspect is discussed in Section 9.3.

SS removal in the BVF was also erratic and averaged 32 percent (reference Figure 8.8 and Table 8.7). Experience with conventional (unstirred) BVF reactors suggests a somewhat higher SS removal can be expected. While a number of factors may have contributed to the erratic and lower-than-expected SS removals, the major factor is believed to be the daily 1 to 2-minute agitation given the model. In a full-scale BVF, the modified mode of operation is less likely to affect the SS removal to the same degree; this is due to the fact that a relatively large quiescent zone is provided in the reactor for settling and recycling of the solids.

9.2 Performance of Aerated Pond

The performance of the 10-day, complete-mix, aerated pond model, at 25°C, was very good (reference Table 8.9). The COD, BOD, SS and NH_3 removals averaged approximately 32, 92, 77, and 96 percent, respectively. The pH of the influent and effluent varied somewhat, but was in the order of 8 and 9, respectively. The average BOD loading was 0.055 $kg/m^3.d$. For practical reasons, the aerobic model was operated in the complete-mix mode.

The COD removal was not very high, as expected, for the anaerobic pretreatment stage (the BVF) removed most of the easily biodegradable substances, leaving mostly biologically refractory organics in the effluent. The BOD and SS removals are typical for the loading and temperature used here.

The performance of a full-scale aerated pond would deteriorate in the winter months as the temperature of the pond fell. The most seriously affected parameter would likely be the ammonia removal (provided the major mechanism for removal is nitrification and not stripping). This should be the case as experience

has shown that a significant degree of nitrification does not occur below a temperature of 15°C. The temperature in a 10-day aerated pond should fall below this critical temperature during the winter months in Northern climates.

In light of the assumption that the BVF and aerobic effluents must be nontoxic to fish, and in view of the fact that the results here indicated incomplete nitrification (i.e., aerobic effluent ammonia concentrations averaged 9.9 mg/L), a simple polishing pond is precluded in favour of a nitrification-activated sludge system. Such a system is more compact, costly and complex, in terms of operation.

Following nitrification, the effluent will contain a relatively high level of nitrate and possibly some nitrite. The nitrite level should be low, as it is usually quickly oxidized to nitrate.[21] The nitrate could present a problem if the effluent should enter a water course or aquifer used for potable or livestock watering purposes. Low levels of nitrite can also be a problem, as concentrations as low as 1 to 3 mg/L are toxic to trout.[20]

An alternative to discharge of the nitrified effluent directly into the environment would be storage and natural dilution in an excavated bog. This approach should preclude the above problems and could prove more acceptable to the regulatory agencies. During the long storage period, the effluent should undergo extensive denitrification. There should be little chance of odour nuisance as the nitrified effluent will be very stable, and there will be oxygen feedback into the bog as denitrification takes place.

Perhaps a better approach to nitrification of the anaerobic effluent would be ammonia stripping (and recovery). This approach is presently being studied at ORF. The economics of this alternative would be a strong function of the ammonia concentration of the anaerobic effluent. Ammonia concentrations have been observed to vary in the order of at least 200 to 600 mg/L.[1] Another advantage of stripping is that the nitrate/nitrite problems are eliminated at the same time.

Hydrogen sulfide may also be present in the anaerobic effluent, in concentrations that are toxic to fish and which cause odour nuisance. The actual sulfide concentration will vary with the sulfur content of the WETOX^{R} effluent (a function of sulfur content of the peat, processing conditions and peat slurry concentration) and operating conditions in the anaerobic reactor.

Experience has shown that hydrogen sulfide, at the concentrations observed here, is easily biochemically oxidized in a properly designed and operated aerated pond system.

At this juncture of the peat research program and in light of the unknowns, it would seem appropriate to also focus a research effort on aerobic treatment of anaerobic peat pressate effluents. This research effort will likely be necessary even if present ammonia stripping/recovery work is successful, as it is unlikely that it is cost-effective to achieve ammonia removals to the extent that will preclude the need for nitrification altogether.

9.3 Biogas Generation and Composition, Sludge Accumulation and Chemical Additions

The average specific methane generation rates for the DFF and BVF reactors were found to be approximately 0.31 and 0.35 m^3 CH_4/kg COD destroyed, respectively (reference Tables 8.6 and

8.8); these figures represent 90 percent and 100 percent of the theoretical value. Experience has shown that 85-95 percent recovery of the theoretical methane production is typical. Factors which contribute to incomplete recovery can include CH_4 dissolution in the effluent, bio- and suspended solids accumulation in the reactor, minor errors in gas quantity and composition measurements and other minor experimental errors (e.g., errors in sampling and COD testing).

The biogas composition from both reactors varied from approximately 50 to 85 percent methane throughout the study. The changes in gas composition were primarily in response to changing reactor pH.

The biogas composition for a full-scale system is difficult to predict because it is affected by waste composition and operating conditions in the reactor (e.g., pH, pH changes, stress, etc.). However, the typical methane content is in the range of 65-75 percent.

The hydrogen sulfide concentrations of the biogas were relatively low throughout the study; the maximum concentration for either reactor was approximately 500 ppm (0.05 percent), with levels typically less than 50 ppm. Since peat deposits are relatively low in sulfur, it is unlikely that the raw biogas from WETOX^R peat pressates will have sulfide concentrations high enough to cause serious handling or environmental problems. Regardless of the exact composition, the results of this study reveal that the raw biogas should be a very good fuel gas and certainly suitable for the thermal drying application proposed.

A solids mass balance was made for each reactor. This was done in an effort to quantify the amount of solids digested in the reactors and the rate of solids accumulation. This information is of importance in establishing a preliminary sludge wasting program.

The results of the solids balance for the BVF were discarded when cross-check data on the mass of solids in the reactor at the end of the study showed significant discrepancies. However, the DFF results appear to be reasonable and are summarized below.

TS and TVS in DFF at start of study -
13.8 and 8.3 g, respectively (estimated)

SS and VSS in feed and deposited in the DFF (reference Table 8.3) -
19.6 and 12.6 g, respectively

TS and TVS in DFF at finish of study -
19.2 and 11.1 g, respectively.

The above figures reveal that of the 19.6 g of SS and 12.6 g of VSS deposited in the reactor, 14.2 g of TS (72 percent) and 9.8 g (78 percent) of TVS were destroyed during this relatively short study. The results are actually somewhat better than shown here as biomass generation and accumulation is ignored. Past studies on food processing wastes, where the volatile content of the solids is relatively high (i.e., 90 percent), have shown that approximately 90 percent of the SS deposited in a reactor are digested in a 12-month period.

As expected, the above DFF solids mass balance revealed that there will be some sludge wasting necessary. In the case of a full-scale DFF, sludge wasting will be automatically done on a more or less continuous basis; this is accomplished, inherently, in its design. The BVF will also require sludge wasting on an intermittently continuous basis, but only after several years of operation. The actual wasting schedule can only be established

from operating experience, as it will be significantly affected by the actual SS and VSS levels in the waste. In any case, the BVF should provide a very high degree of volatile solids destruction because of the extremely high SRT this type of reactor provides. Moreover, the BVF can be used to digest any waste-activated sludge produced in the aerobic polishing stage, thus decreasing the overall quantity of treatment plant sludge even further. Provision is made in the BVF design for continuous sludge recycle as a means of enhancing system performance. This same sludge recycle system is used to waste sludge from the reactor.

The ORF WETOX^R peat pressate had a BOD/N/P (N as NH_3) ratio of approximately 250/12/1. This ratio should provide adequate levels of nutrients for both high-rate and low-rate anaerobic systems, without any supplementation. Because of the nature of the waste, it is very doubtful that it would be lacking in any essential micronutrients.

The results of this study indicate that the BVF can be operated without addition of chemicals for pH control; the high levels of ammonia in the WETOX^R peat pressate is responsible for this.

Although not supported by any results from this study, it is felt that the DFF should also operate satisfactorily at moderate loadings without any chemicals for pH control, once it has matured. The maturation period could last up to 12 to 18 months.

This matter of pH control is a very important one, as costs for caustic (NaOH) can be very high. Pilot-scale testing, where on-line pH control can be maintained, is the best way of getting reliable chemical dosage information for a given waste.

9.4 Biological and Fish Toxicity

There was no evidence of biological toxicity or inhibition in either anaerobic reactor during the study. The three main sources of biological toxicity of concern here were furfural, NH_3 and H_2S.

The furfural level of the waste was found to be quite low (ref. Table 5.2), and considerably higher levels have been found nontoxic.[22]

The total hydrogen sulfide levels measured in both the DFF and BVF effluents were found to be relatively low. The low concentrations of sulfide in the biogas and low odour level served as further indications of low sulfide concentration in the effluent.

For sulfide toxicity to occur, the unionized sulfide level must be in the range of 100 to 150 mg/L.[23] With this particular waste and in a well-balanced system, the pH of the reactor should be 7.0 or above, which means that the unionized fraction of the soluble sulfide should be less than approximately 50 percent. This being the case, the soluble sulfide levels in the reactor would have to be in the range of 200 to 300 mg/L for toxicity to occur. It is highly unlikely that these toxic levels of soluble sulfide will occur, especially in light of the fact that the total sulfur content of the pressate is of the same order, i.e., 200-300 mg/L (ref. Table 5.2), and it will not all be in a form available for conversion to sulfide.

There are conflicting reports on the toxicity levels of ammonia.[24] However, for purposes of discussion here, it was assumed that ammonia is toxic at unionized (free ammonia)

concentrations of 150 mg/L in the reactor. The concentration of unionized ammonia increases with increasing pH. The typical range of operating pH for full-scale reactors is 6.5 to 8.0. At a pH of 8.0, approximately 7 percent of the ammonia is unionized. The above figures translate to a total ammonia concentration of 2150 mg/L (i.e., 150 mg/L/0.07) before severe toxicity is observed. At lower reactor pH, the toxic ammonia concentration will increase in response to a lower fraction of unionized ammonia.

In view of the ammonia levels observed here in the pressate (ref. Table 5.2), the anaerobic effluents (ref. Table 9.2) and elsewhere,[1] it is unlikely that ammonia toxicity will be a problem. However, if it does occur, it can be solved by the addition of acid to reduce the reactor pH.

Two factors which could void the above argument against the possibility of ammonia toxicity are: 1) the processing of peat at significantly higher solids concentrations and 2) recycling of pressate to the WETOX^{R} reactor. Both of these process variations will lead to higher ammonia concentrations in the pressate effluent.

Hydrogen sulfide and ammonia are of concern in regard to fish toxicity. Hydrogen sulfide is believed to be a nonissue here, provided the anaerobic effluent is treated aerobically. Ammonia concentrations in the pressate and anaerobic effluent are high (ref. Tables 5.2 and 8.2, respectively), and the effluent will be very toxic to fish. Ammonia is toxic to trout at a unionized concentration of 0.15 mg/L. Assuming that an aerobic polishing system will operate at a pH of 8.0 and temperature of 20°C, the total effluent ammonia concentration cannot be higher than 4 mg/L or the toxic level of 0.15 mg/L unionized ammonia will be exceeded. In order to achieve such low ammonia levels, a nitrification-activated sludge system is necessary.

In the nitrification system, ammonia is oxidized to nitrate and some is stripped to atmosphere. Nitrate is reported to be toxic to trout at concentrations of 5000-6000 mg/L.[20] It is unlikely that nitrate will be a problem at the concentrations anticipated here (i.e., 900 mg/L NO_3 from 200 mg/L NH_3). However, there is a potential for fish toxicity if there are significant nitrite (NO_2) residuals in the effluent; there are conditions, apparently, under which this can occur. Nitrites are reported to be toxic to trout at 1-3 mg/L.[20]

While nitrates may not be a problem to fish, they can be a potential problem where the effluent enters a stream or ground water destined for human or livestock consumption. A nitrate limit of 45 mg/L is recommended for domestic water supplies.[21] Another potential nitrate problem is eutrophication in a receiving stream.

In light of the potential problems noted above with regard to nitrates and nitrites, there are obvious benefits for final disposition of the aerobic effluent in an excavated bog area. (Perhaps disposal in this manner may also preclude extensive aerobic polishing.) The benefits of discharging to bog would include:

1. significant dilution before discharge to a receiving stream, and

2. during the storage period, the effluent would undergo a significant degree of denitrification and thereby be less of a problem to the environment.

9.5 VA Results

Table 8.1 presents a comparison of VA results by titration method[16] (used by ADI) and gas chromatography (GC). The ADI samples were preserved with sulfuric acid and shipped periodically to the NRCC Laboratory in Ottawa (Biological Sciences Division) for GC analysis.

This comparison shows quite conclusively that the titration method consistently gives results which are significantly higher than from the GC method. Therefore, the reader is cautioned that the VA results reported here may be high by at least as much as 50 percent, and even 1000 percent in some cases.

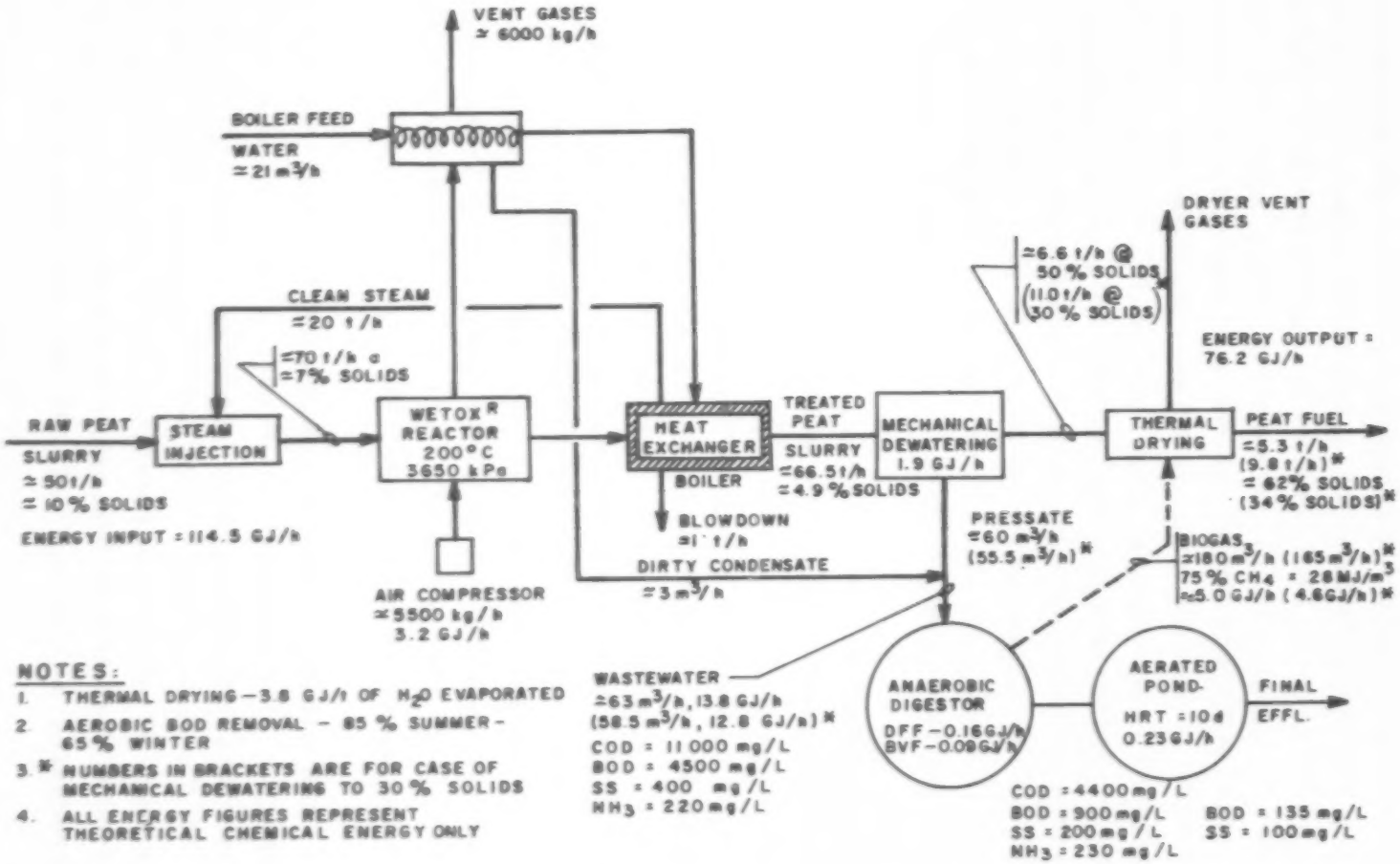
While the VA titration method has been shown to have severe shortcomings, it has proven itself to be a useful tool for day-to-day reactor control purposes. The test is quite easy and short, and changes in VA levels are readily noted.

10.0 MASS AND ENERGY BALANCE

A basic mass and energy balance was developed for a hypothetical, partial WETOX^{R} system having a throughput of 50 tonnes per hour of 10 percent peat slurry (reference Figure 10.1). The peat slurry is diluted and preheated with steam before being pumped into the WETOX^{R} reactor. In the reactor, the peat slurry is mixed with a controlled amount of air and brought to reaction temperature. There are four separate, agitated compartments in the reactor. Approximately 10 to 11 percent of the peat is oxidized in the process[2], and another 10 to 11 percent is solubilized. The gas and liquid phase reactor effluents are used to supply energy for preheating of the cold peat feed slurry. The cooled, treated peat is then mechanically dewatered. Preliminary work suggests that the resultant cake will have a solids content of the order of 50 percent.

The process rate of 50 wet tonnes per hour is considered to be the maximum for a single WETOX^{R} reactor.[1] If additional capacity is needed, other units can be added in modular fashion. While it has been indicated that the largest practical size of the anaerobic reactor also places limits on the maximum system throughput,[1] experience has shown this not to be the case.

The gross calorific values of raw and final product peat used here are 22.9 and 23.1 MJ/kg, respectively, and are the actual values reported by ORF (reference Table 5.1). A raw peat slurry of 10 percent solids (before steam addition and 7 percent after steam), a "treated" peat slurry concentration of 4.9 percent



NOTES:

1. THERMAL DRYING – 3.8 GJ/t OF H_2O EVAPORATED
2. AEROBIC BOD REMOVAL – 85 % SUMMER – 65 % WINTER
3. * NUMBERS IN BRACKETS ARE FOR CASE OF MECHANICAL DEWATERING TO 30 % SOLIDS
4. ALL ENERGY FIGURES REPRESENT THEORETICAL CHEMICAL ENERGY ONLY

FIG 10.1 : MASS AND ENERGY BALANCE

solids, and an overall solids recovery of 66 percent were assumed. The wastewater characteristics shown for the WETOX^{R} effluent in Figure 10.1 are only approximate values. An anaerobic COD removal of 60 percent and a specific methane generation rate of 0.32 m^3 CH_4/kg COD removed (90 percent of theoretical) were used, based on the findings of this study. The energy content of the WETOX^{R} effluent (i.e., 13.8 GJ/h @ 63 m^3/h or 12.8 GJ/h @ 58.5 m^3/h) was calculated assuming a TS concentration of 9500 mg/L and a gross calorific value of 23 MJ/kg of effluent dry solids. For thermal drying, in a conventional rotary or flash type system, a figure of 3.8 GJ of heat required per tonne of water evaporated was assumed.

The energy balance is not complete, as its purpose was merely to show the approximate amount of energy recovered through anaerobic treatment, in the form of biogas. As a percentage of the total energy content of the peat-derived fuel (i.e., 76.2 GJ/h), the biogas contains approximately 6.0 to 6.5 percent, i.e., 4.6 to 5.0 GJ/h. Approximately 40 percent of the total waste energy contained in the untreated effluent is recovered as biogas. For purposes of Figure 10.1, the biogas was assumed to contain 75 percent methane. It has been proposed to utilize this biogas in a thermal dryer,[1] to increase the total solids content of the final peat fuel product. For a more complete mass and energy balance, refer to Section 323.61 in Reference 2.

Regarding the matter of solids content of the peat-derived fuel, two scenarios are presented in Figure 10.1. In one scenario, the mechanical dewatering step produces a cake of 50 percent solids (6.6 t/h), which is dried thermally with biogas to approximately 62 percent solids (5.3 t/h). In the second case, it is assumed that the mechanical dewatering step is less effective, producing a cake of only 30 percent solids (11.0 t/h),

which is further dried to approximately 34 percent solids (9.8 t/h). The numbers for the second scenario appear in brackets in Figure 10.1.

In summary, the anaerobic treatment system makes a very significant contribution or savings to the overall energy output of the WETOX^{R} system. The total savings, by anaerobic treatment, cannot be fully appreciated until one compares it to conventional aerobic treatment. Aerobic treatment is a net consumer of large amounts of energy due to the power requirements for aeration and other equipment.

11.0 ECONOMIC ANALYSES

The capital and annual operating and maintenance costs for the DFF and modified BVF anaerobic reactors were developed for a hypothetical, partial WETOX^{R} system processing 50 tonnes per hour of 10 percent solids peat slurry. These costs also include allowance for Capital and O & M Costs for a 10-day aerated pond. The capital costs for treatment would benefit significantly through economy-of-scale for larger WETOX^{R} capacity plants. The treatment capacity where an economy-of-scale factor would no longer apply is somewhat site specific and dependent also on the type of anaerobic reactor; however, it is significantly higher than the waste loading from a 50 wet tonne per hour partial WETOX^{R} plant.

The treatment systems proposed were designed to handle approximately 60 m^3/h of wastewater having a COD/BOD of 11 000/ 4 500 mg/L (reference Figure 10.1). The actual wastewater flow and its characteristics will be dependent on the efficiency of the treated peat dewatering system and the WETOX^{R} processing conditions. The basic design criteria and assumptions used in the economic analysis and components of the system specifically included (or excluded) appear in Appendix B.

Design COD loadings of approximately 8.0 and 1.7 kg/m^3.d for 60 percent COD removal were assumed for the DFF and modified BVF, respectively, for development of capital costs. These criteria resulted in reactor volumes of approximately 2000 m^3 and 9000 m^3 for the DFF and BVF, respectively.

The estimated capital costs for the DFF and BVF are approximately $2.2 and $1.4 million, respectively (reference Appendices C and D). The annual operating and maintenance costs for the DFF and BVF (and aerated pond) are approximately $135 000 and $110 000, respectively.

The above capital costs include an engineering and contingency allowance of 30 percent. The annual costs include allowance for an operator/technician for one full shift position, seven days per week. There was no allowance made for chemicals for pH control or nutrients in either the DFF or BVF system.

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- Miss Anne Tennier, Laboratory Manager, ADI Limited;

- Mr. Kevin Conrod, Environmental Technologist, ADI Limited.

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APPENDIX A

ORF REPORT ON WET OXIDATION OF PEAT

RESEARCH

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ADI Limited
P.O. Box 44, Station A
Fredericton, N.B.
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July 23, 1984

Attention: Mr. Al Cocci

REPORT NUMBER 48-20273

IDENTIFICATION Your P.O. No. 15737

SPECIFICATIONS OF ORDER Wet Oxidation of Peat

OBJECTIVE

The objective of the program was to generate up to 150 gallons of wet oxidized peat filtrate for subsequent digestion studies by ADI.

DESCRIPTION OF PEAT

Peats used for all wet oxidation tests were collected in September, 1983, from a bog located approximately 40 kms west of Quebec City, abou⁺ 2 kms south of highway 20. Two different types of peat were collected:

(1) a "medium" humified peat with a von Post classification of H5 → H6.

(2) a "high" humified peat with a von Post classification of H8 → H9.

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EXPERIMENTAL PROCEDURE

(Refer to Appendix for description of Wetox(R) system employed for runs).

Due to pump wear, we were unable to process the required amount of feed peat in one run.

Three separate generation runs were accomplished over a period of several months.

The conditions maintained in the Wetox System were as follows:

	Temp ^{o}C	198 → 201^{o}C
	Pressure (psi)	500 → 550 psi AIR
	Feed Flow Rate	400 → 500 mL/min.
*	LPE Flow	390 → 490 mL/min.
**	VPC Flow	≈10 mL/min.
	Air Flow	≈1.0 scfm
		Peat Mixture - 52% "High" - 48% "Medium"

* Liquid phase effluent

** Vapour phase effluent

After processing, the liquid phase effluent was filtered through 15.0 cm, 541 WHATMAN filter paper in an appropriate BUCHNER funnel apparatus. The filtrate was then mixed with the VAPOUR PHASE EFFLUENT and was then put into a plastic barrel for shipping.

Analysis of the peat before and after processing was as follows:

Peat Feed:	T.S.	-	70,674 mg/L
	COD	-	98,920 mg/L
Liquid Phase Effluent (Before Filtering):	T.S.	-	46,950 mg/L
	COD	-	74,920 mg/L
Liquid Phase Effluent (After Filtering):	COD	-	10,800 mg/L
	BOD	-	5,112 mg/L
	Furfural	-	7.54 mg/L
Vapour Phase Effluent:	COD	-	6,500 mg/L

The average flowrate of VPC was approximately 2.0 → 2.5% of the feed flowrate. The COD of the "total" effluent, therefore, was approximately 73,000 mg/L.

A. Stevenson

att.

AS/ek

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ORE

APPENDIX

1-10 Unit

EQUIPMENT

The continuous flow Wetox$^{(R)}$ 1-10 unit has a total volume of 10 litres with an active liquid capacity of 5 litres. The inside lining of the reactor and all wetted parts are made of titanium. The process flowsheet is presented in Figure 1.

Agitation

The reactor is equipped with a magnedrive stirrer with a range of 0 → 1500 rpm.

Heating

Two sets of heaters are used to heat the reactants. Electrically heated, Dowtherm heat transfer oil is circulated around the outside of the jacketted vessel.

In general, this heating system remains on throughout a run, as the response time to temperature fluctuation is too sluggish for accurate temperature control.

Electrical rod heaters are fixed onto the feed pipe leading to the reactor immediately following the Wetox process heat exchanger. On-off operation of these heaters is controlled via a temperature sensor and relay mounted on the effluent line of the vessel. Because these heaters respond quickly to reactor temperature changes, they are used for primary temperature control. At steady state, a system temperature variation of less than $\pm$ 5°C is observed.

Reactor Pressure and Air Supply

Compressed air is supplied from a bank of 5 cylinders. The inlet air flowrate is controlled by a micrometer inlet valve. The exit air flowrate, and hence, pressure, is controlled by a Masoneilan Micropak Control Valve.

A rupture disc (1200 psi) is provided on the reactor. Maximum normal operating pressure of the equipment is 700 psi.

Feed System

The feed sample is located in a 40 gallon head tank located beside the pump. The feed tank is equipped with an agitator to ensure homogeneous feeds.

Liquid System

The feed liquid is pumped via a high pressure Moyno progressive cavity type pump through a tube in tube heat exchanger, countercurrently to the process effluent streams. Thereafter, the hot liquid flows through a set of strap-on preheaters prior to entering the reaction vessel.

The liquid level inside the vessel is maintained with a capacitance type probe which, when activated, signals on-off operation of a control valve located after the process heat exchangers.

Vapour System

Compressed air is added continually to the system at the bottom of the vessel below the stirrers. As air is added to the system, its total pressure increases until it exceeds the desired maximum and then a pressure-regulated valve is activated.

All exiting gas is passed through the heat exchanger in which the steam is condensed. The vapour is then further cooled and collected separately.

TEST PROCEDURE

(1) Fresh water is pumped into the reactor until the unit is filled; pump is then stopped.

(2) The reactor heaters are turned on (Not Preheaters).

(3) System is allowed to heat to ∿ 10°C above temperature required.

(4) The desired pressure and flowrate of air is then adjusted.

(5) The pump and preheaters are turned on and adjusted accordingly.

(6) Off-gas is monitored for oxygen concentration.

(7) Feed is pumped for ∿ 2 reactor volumes to achieve steady-state concentrations throughout the process.

(8) Samples of LPE and VPC can then be collected.

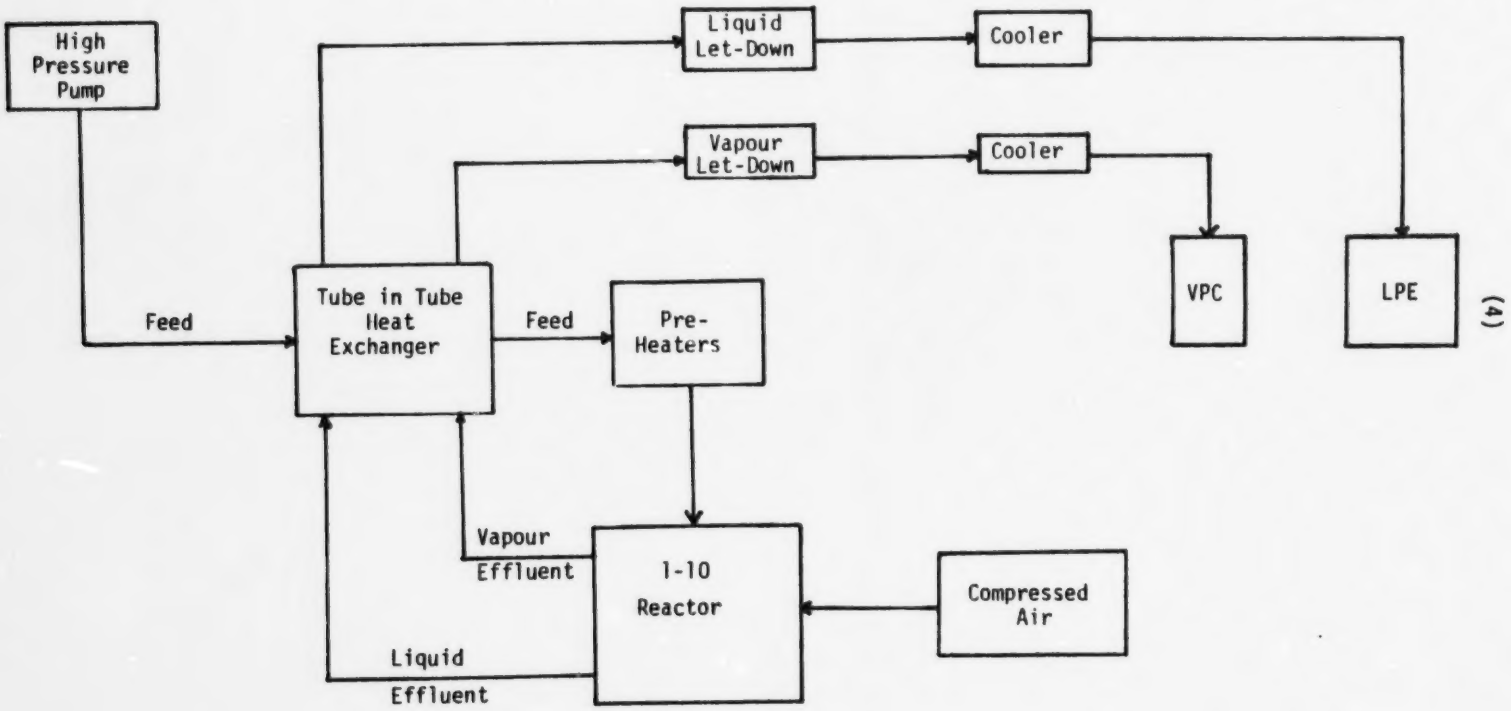

FIGURE 1 - Continuous Flow 1-10 Unit

(4)

APPENDIX B

PRELIMINARY, FULL-SCALE DESIGN CRITERIA AND ASSUMPTIONS

APPENDIX B

PRELIMINARY, FULL-SCALE DESIGN CRITERIA AND ASSUMPTIONS

1. WETOX^{R} processing capacity - 50 t/h @ 10 percent solids, peat slurry
2. WETOX^{R} effluent flow rate - 60$^{+}_{-}$ m^3/h
3. WETOX^{R} effluent COD - 11 000 mg/L
4. DFF design criteria - 60 percent COD removal (80 percent BOD removal) for a loading of approximtely 8.0 kg COD/m^3.d
5. "Modified"-BVF design criteria - 60 percent COD removal (80 percent BOD removal) for a loading of approximately 1.7 kg COD/m^3.d
6. Aerated Pond design criteria - BOD load = 0.09 kg/m^3.d and 85 percent BOD removal summer, 65 percent winter
7. BOD/N/P requirements - 250/5/1
8. From No. 7 above, supplemental nitrogen or phosphorus addition is <u>not</u> required
9. No pH control chemicals required
10. WETOX^{R} effluent temperature to anaerobic - 35 to 40°C
11. Methane yield - 0.32 m^3 (STP)/kg COD removed
12. Treatment plant operation - 24 h/d, 365 d/a
13. Cost of electricity - 5.0¢/kWh
14. Treatment plant staffing requirements - one operator/technician for day shift only; special analytical testing can be done by process plant lab; maintenance and routine surveillance can be done during night shift by routine maintenance personnel; no allowance for supervision or administration

15. Higher heating value of methane - 37.25 MJ/m^3

16. No allowance for cost of land for treatment facilities

17. 1 kW of aeration removes 18 kg BOD/d

18. No allowance for cooling or heating equipment for anaerobic reactor influent

19. No allowance for pumping system for WETOX^R effluent to reactor

20. BVF requires 12 mm insulated cover, and DFF reactor and equalization tank requires 75 mm of insulation

21. Length of biogas force main from reactor to thermal dryer - 150 m for DFF and 450 m for BVF

22. Suitable clay is available for impermeable earth pond construction, 5 km from site

23. Each reactor includes steam line from process plant or a dedicated boiler for heating purposes during start-up or other times when reactor heating is necessary

24. No allowance for outfall to receiving stream

25. No allowance for local taxes and insurance

APPENDIX C

DFF PRELIMINARY CAPITAL COST ESTIMATE ($2\ 000\ m^3$ DFF + $15\ 000\ m^3$ Aerated Pond)

APPENDIX C

DFF PRELIMINARY CAPITAL COST ESTIMATE
(2 000 m^3 DFF + 15 000 m^3 Aerated Pond)

		$ 1984
1.	Insulated equalization tank (1500 m^3), pumps, piping, valving and mixer, insulated glass-lined reactor tank (2500 m^3) c/w insulated tank cover, inlet and outlet header system, media (2000 m^3), recycle system, chemical feed system, samplers, flow, temperature and pH monitoring equipment, all electrical and miscellaneous piping, valves, structures, etc.	$1 100 000
2.	Biogas collection and utilization system c/w building, biogas blowers, flare and vent system, all controls and safety valves, biogas flow and monitoring equipment, gas distribution piping, and dedicated boiler or steam line allowance	180 000
3.	Aerated pond site preparation, excavation, backfill, imported clay liner, yard piping, inlet/outlet chambers, aerators (75 kW installed), riprap, controls, etc.	350 000
4.	Site services including power supply to site, fresh water supply, grading, roadway, landscaping, allowance for reactor seed sludge and start-up chemicals and heat	70 000
	Subtotal	$1 700 000
5.	Engineering and contingencies @ 30 percent	500 000
	TOTAL	$2 200 000

APPENDIX D

BVF PRELIMINARY CAPITAL COST ESTIMATE ($9\ 000\ m^3$ BVF + $15\ 000\ m^3$ Aerated Pond)

APPENDIX D

BVF PRELIMINARY CAPITAL COST ESTIMATE ($9\ 000\ m^3$ BVF + $15\ 000\ m^3$ Aerated Pond)

		$ 1984
1.	BVF site preparation, excavation, backfill and imported clay liner	$ 85 000
2.	Insulated membrane cover, biogas collector, yard piping, chemical feed system, chambers, valving, inlet and outlet headers, samplers, temperature/pH monitoring equipment, flow meter, electrical, etc.	360 000
3.	Biogas system and dedicated boiler or steam line (as per Appendix C, Item 2)	180 000
4.	Aerated pond (as per Appendix C, Item 3)	350 000
5.	Site services (as per Appendix C, Item 5)	70 000
	Subtotal	$1 045 000
6.	Engineering and contingencies @ 30 percent	315 000
	TOTAL	$1 360 000

APPENDIX E

ESTIMATED ANNUAL OPERATING AND MAINTENANCE COSTS FOR DFF AND BVF

APPENDIX E

ESTIMATED ANNUAL OPERATING AND MAINTENANCE COSTS FOR DFF AND BVF

		$ 1984 DFF	BVF
1.	Staffing - one operator/technician	$ 35 000	$ 35 000
2.	Electrical Costs		
	a. DFF 45 kW	20 000	--
	b. BVF 25 kW	--	11 000
	c. Aerated pond 65 kW	28 500	28 500
3.	Chemicals*		
	a. for pH control	nil	nil
	b. nitrogen	nil	nil
	c. phosphorus	nil	nil
4.	Maintenance @ 2 percent of Total Capital Cost		
	DFF plus aerobic 0.02 x $2 200 000	44 000	
	BVF plus aerobic 0.02 x $1 360 000		27 200
5.	Miscellaneous Supplies, allowance	5 000	5 000
	TOTALS	$132 500	$106 700

*Allowance for start-up chemicals included in capital cost

1.0 CONCLUSIONS ET RECOMMANDATIONS

1.1 Conclusions

Les principales conclusions tirées de la présente étude sont énumérées ci-après, en plusieurs points.

1. Les résultats de l'étude indiquent que la tourbe comprimée WETOX^{MD} peut être traitée efficacement à la fois dans le FED à haut rendement et dans le FHC à faible rendement.

2. Les résultats de l'étude et l'expérience acquise dans ce domaine laissent penser qu'il est raisonnable (et prudent) de prévoir, au stade de la conception préliminaire, des charges respectives en DCO de 8,0 kg/m^3.d et de 1,7 kg/m^3.d pour le FED et le FHC, pour une élimination de la DCO d'environ 60%.

3. Les limites réalistes de l'élimination de la DCO et de la DBO sont respectivement de l'ordre de 60-70 % et de 80-90%.

4. Il est possible de récupérer environ 40% de l'énergie chimique de l'effluent de tourbe comprimée sous forme de biogaz grâce au traitement anaérobie. Ce biogaz contient environ, 6,0 à 6,5% de l'énergie totale du combustible dérivé de la tourbe.

5. Le taux de production de biogaz des réacteurs était normal: le taux spécifique de production de méthane s'élevait en moyenne à 0,31 et 0,35 m^{3}CH^4/kg DCO éliminée respectivement pour le FED et le FHC.

6. La concentration de méthane dans le biogaz variait de 50 à 85 % environ, surtout en fonction des variations de pH à l'intérieur des réacteurs. A l'échelle réelle, la composition du biogaz varierait moins et la teneur en méthane devrait se situer aux environs de 65 à 75%. Dans les deux réacteurs, la concentration de sulfure d'hydrogène était relativement faible à l'échelle réelle, h, elle ne devrait pas poser de problème sérieux du point de vue de la manutention et de l'environnement.

7. Le biogaz brut devrait s'avérer excellent pour sécher thermiquement le combustible dérivé de la tourbe; il est produit en quantité suffisante pour faire passer la teneur en solides de la tourbe essorée mécaniquement de 50 à 62%. Au cas où il faudrait obtenir une teneur plus élevée en solides, le combustible dérivé de la tourbe peut aussi servir de source de combustible pour le séchage.

8. Il n'y a eu de signes de toxicité ou d'inhibition biologiques dans aucun des deux réacteurs anaérobies. La toxicité due au furfural, au sulfure d'hydrogène ou à l'ammoniaque est peu probable à moins que les caractéristiques de la tourbe comprimée ne varient énormément par rapport à celles qui ont été observées dans la présente étude.

9. On pense que la perturbation observée dans le FED a été causée par faible pH à l'intérieur du réacteur résultant d'une baisse délibérée de l'alcalinité. On considère qu'il ne sera pas nécessaire d'ajouter de produits chimiques pour ajuster le pH dans le cas de charges modérées une fois que les réacteurs auront atteint leur maturité.

10. Les résultats de la présente étude indiquent qu'il y a suffisamment de macro- et de micro-éléments nutritifs dans la tourbe comprimée WETOX^{MD} pour que la fermentation anaérobie soit possible.

11. Les données portant sur le bilan massique des solides indiquent qu'environ 75 % des solides en suspension retenus dans les réacteurs ont subi une digestion anaérobie pendant le peu de temps qu'a duré la présente étude. Avec le temps, ces solides se dégraderont encore plus.

12. L'élimination des déchets solides sera nécessaire dans les deux réacteurs. Le FED est conçu pour que cette élimination se fasse automatiquement. Dans le cas du FHC, l'élimination des déchets solides ne deviendra nécessaire qu'après plusieurs années de fonctionnement, lorsque la qualité de l'effluent commencera à se dégrader à cause de la présence d'un excès de boue dans le réacteur. Comme le temps de rétention des matières solides (TRS) est élevé dans le cas du FHC, celui-ci peut permettre la digestion d'une proportion très élevée des solides

volatils et être utilisé comme digesteur avec n'importe quel déchet de boue aérobie.

13. Les concentrations d'ammoniaque et peut être aussi de sulfure d'hydrogène dans l'effluent anaérobie seront toxiques pour la truite. Le traitement aérobie traditionnel éliminera le sulfure d'hydrogène et fera baisser encore plus la DBO; cependant, pour s'assurer qu'on réduit adéquatement la concentration d'ammoniaque pour obtenir un effluent non toxique, il faudra ajouter un système de nitrification. Ce genre de système est plus coûteux, plus complexe et plus difficile à faire fonctionner.

14. La concentration de nitrates dans l'effluent aérobie ne devrait pas être toxique pour le poisson; il y a cependent risque de toxicité due aux nitrites si, au moment du rejet, l'effluent contient une quantité non négligeable de résidus.

15. Si l'effluent n'est pas suffisamment dilué avant d'atteindre les cours d'eau ou les nappes aquifères qui servent à l'approvisionnement en eau potable, une teneur élevée en nitrates peut être une source d'inquiétude.

16. Il serait peut-être préférable de rejeter l'effluent nitrifié dans une excavation pratiquée dans une tourbière plutôt que de le rejeter directement dans un cours d'eau. En disposant de l'effluent de cette manière, on éviterait l'affinage aérobie extensif. Dans la tourbière, on obtiendrait une dilution supplémentaire et une dénitrification importante.

17. On peut remplacer la nitrification par une épuration à l'ammoniaque. Il est cependant improbable qu'on puisse appliquer ce procédé de manière rentable et qu'il soit suffisamment efficace pour éliminer complètement l'étape de la nitrification.

18. On estime les coûts en capital pour la réalisation d'un FED et d'un FHC à l'échelle réelle, complets avec bassin d'aération décadaire, à environ 2,2 millions de dollars et 1,4 millions de dollars respectivement. Ces coûts correspondent a des systèmes permettant de traiter les effluents provenant d'une usine de WETOX^{MD} où passent 50 tonnes métriques de bouillie de tourbe contenant 10 % de solides, à l'heure. Il est possible de concevoir et

de construire des réacteurs anaérobies plus gros à un coût unitaire plus faible. Cette différence est particulièrement sensible dans le cas du FHC parce qu'on utilise un bassin en terre. On estime à 135 000 $ et à 110 000 $ respectivement, les frais annuels d'opération et d'entretien du FED et du FHC modifié.

1.2 Recommendations

Les recommendations suivantes sont formulées à la lumière des constatations faites au cours de la présente étude:

1. Il est conseillé d'entreprendre une étude à l'échelle pilote ou expérimentale pour vérifier les critères de conception préliminaires qui s'appliquent aux systèmes anaérobies présentés.

2. Les recherches devraient être poursuivies pour trouver d'autres méthodes de traitement des effluents par voie anaérobie et pour examiner les aspects suivants: élimination de l'ammoniaque, nitrification et même, éventuellement, toxicité.

3. Le rejet de l'effluent nitrifié (en totalité ou en partie) dans une excavation pratiquée dans une tourbière, semble présenter des avantages incontestables. Il reste encore à déterminer l'impact global qu'un tel rejet aura sur l'environnement et s'il y a lieu d'envisager sérieusement cette solution à l'échelle réelle.